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EVALUATION OF THE IBM PATIENT PHYSIOLOGICAL MONITORING SYSTEM,(U)
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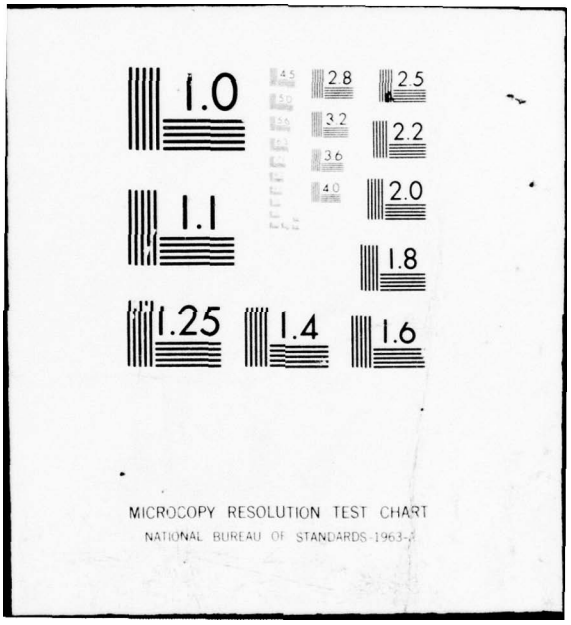
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Medical Systems Div.

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DEPARTMENT OF THE AIR FORCE
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FOR THE CHIEF OF STAFF

Melvin B. Dobbs

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Chief, Medical Systems Division
Office of the Surgeon General

1 Atch
IBM Patient Physiological Monitoring System Evaluation

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EVALUATION OF THE

IBM PATIENT PHYSIOLOGICAL MONITORING SYSTEM

ABSTRACT

The IBM Patient Physiological Monitoring System (PPMS) is a respiratory oriented system which provides data on cardiac and respiratory functions as well as vital signs. PPMS was tested in the Intensive Care Unit (ICU) of Wilford Hall USAF Medical Center, Lackland AFB, Texas, during 1 July through 31 December 1976, and was linked by telephone to a computer at Mt. Sinai Medical Center, New York City. The test was conducted to determine the degree to which the system fulfills its objective of improving the delivery and outcome of patient care, the acceptance of the system by operating personnel, and the economic feasibility of the system in the military setting.

Findings were based on data concerning the treatment and outcome of care for 81 patients monitored using standard minitoring techniques, 82 patients monitored using PPMS, opinion survey results, and the system internal record of inquiries. Data concerning the treatment and outcome of care indicates that PPMS fulfills its objective of improving the delivery and outcome of patient care to some extent. In particular, there was improvement in the average length of stay in the ICU, the average time of ventilatory support required, and in the occurrence of pneumonia, arrhythmias, myocardial failure, oliguria, and anuria. It further indicates that the drug requirements of the two groups were different but reflected appropriate treatment of the existing medical problems. The net result of these changes is that there is some indication that PPMS is cost effective. Opinion questionnaire results and the systems

internal record of utilization indicate that PPMS was accepted by anesthesiologists and blood gas technicians but not by thoracic surgeons. Nurses' acceptance of PPMS is uncertain. In addition, opinion questionnaires indicated that PPMS did not permit freedom from administrative detail, but did increase awareness of the constantly changing physiological states of patients for some user categories.

In conclusion, it has been demonstrated that PPMS is, to some extent, beneficial to seriously ill patients, and is potentially cost effective. It is therefore recommended that patient physiological monitoring efforts continue in the Air Force and Department of Defense. It is not recommended that PPMS be proliferated as it now exists because of certain features which surgeons and nurses do not like. It is recommended that the Tri-Service Medical Information System (TRIMIS) Program Office procure a prototype system competitively. Such a system should be a complete package having capabilities to satisfy all user groups, i.e., thoracic surgeons, anesthesiologists, nurses, and blood gas technicians.

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IBM PATIENT PHYSIOLOGICAL MONITORING SYSTEM

SECTION A - INTRODUCTION

1. Background.

a. System Description. The IBM Patient Physiological Monitoring System (PPMS) is a respiratory oriented system which provides data on cardiac and respiratory functions as well as vital signs. PPMS measures eight basic patient parameters using standard medical devices and inputs them directly into a computer. Blood gas and chemistry are entered manually. These measurements are used to derive the values of 20 additional parameters. Parameters which are measured and derived are listed in Appendix A.

PPMS is programmed to update all patient parameters every 10 minutes following the collection of 30 seconds of respiratory data and 10 seconds of cardiovascular data. If more recent information is required, demand or continuous mode monitoring may be requested. If information is requested on demand, the values of the parameters are available in 38 seconds. Thirty seconds is required to gather data from a sample, and eight seconds is required to process the data. If continuous mode monitoring is selected, the values of the patient parameters are calculated and displayed every minute.

Visual displays include alphanumeric TV display, 4, 12, and 24 hour graphic trend plots; and the system provides hard copy capability. The video display monitor

may be used to obtain vital signs reports, shift, daily, and periodic timed reports, historical displays, trend assessment displays, multiple parameter display, and graphic display of parameter correlations. The instruments used to obtain measurements are given in Appendix B.

b. History. PPMS originated from an IBM research program with Pacific Medical Center in 1965. The contribution to medicine is attributed mostly to Dr John J. Osborn, Director of the Cardio-pulmonary Intensive Care and Clinical Research Unit. The cart used during the evaluation was modified at the Mt. Sinai Medical Center in New York City.

c. Evaluation. PPMS was tested in the Intensive Care Unit of Wilford Hall USAF Medical Center, Lackland AFB, TX, during the period 1 July through 31 December 1976. The test and evaluation resulted from an unsolicited proposal by IBM. This proposal, which was recieved by the Air Force on 14 June 1975, called for the joint demonstration and evaluation of a patient physiological monitoring system.

The test and evaluation of PPMS was an approved TRIMIS project. The Army and Navy were invited to participate but did not respond.

2. Responsibilities.

a. IBM was responsible under contract with the US Air Force for the following:

(1) The removal of one Cardio-Pulmonary Patient Monitoring unit from Mt. Sinai Hospital in New York City.

(a) The testing and checkout of the patient monitoring unit under simulated operating conditions at their facility in Gaithersburg, Maryland.

(b) The installation of the patient monitoring unit in the Intensive Care Unit of Wilford Hall USAF Medical Center.

(2) The return packing and shipment of the patient monitoring unit to Mt. Sinai Hospital to include disconnection.

(3) Technical support for the patient monitoring unit while at Lackland AFB, Texas.

(4) A minimum of two man weeks (10 days) of manpower support in the development and determination of an evaluation protocol.

(5) Dealing directly with Mt. Sinai Medical Center in coordinating the testing and removal of the patient monitoring unit.

b. Mt. Sinai Medical Center was responsible for providing the following under contract with the US Air Force:

(1) One patient monitoring unit which was located at Mt. Sinai Medical Center.

(2) Twenty-four hour computer processing capability from Mt. Sinai to the patient monitoring unit located at Wilford Hall.

(3) Two Teledynamic Modems. One Model 7278 was to be located at Mt. Sinai Medical Center, and one Model 7201B was to be located at Wilford Hall USAF Medical Center.

(4) A user's manual for the patient monitoring unit for use by Wilford Hall USAF Medical Center.

(5) On site training for each of at least two Wilford Hall USAF Medical Center personnel.

(6) Facilities, space, tools, special test equipment, and computer time for IBM to test and check out the patient monitoring unit before it was shipped.

(7) Clinical and technical consultations as needed.

(8) One Marquette Six-Channel Transmitter and Receiver.

c. USAF Responsibilities under contract with IBM.

(1) When installation and checkout of the patient monitoring unit and other government equipment were completed, Wilford Hall USAF Medical Center was to accept responsibility for the care and safeguarding of the equipment.

(2) Wilford Hall USAF Medical Center was to accept all professional, administrative, and legal responsibilities for normal and special patient care and all hospital functions associated with this effort.

d. The US Air Force was responsible for the following under contract with Mt. Sinai Medical Center.

(1) All normal maintenance and labor costs not provided for under contract with IBM.

(2) Travel, lodging, and meals for personnel receiving training at Mt. Sinai Medical Center.

(3) When installation and checkout of the patient monitoring unit were complete, Wilford Hall USAF Medical Center was to accept responsibility for the care and safeguarding of equipment.

(4) Wilford Hall USAF Medical Center was to accept all professional, administrative, and legal responsibilities for normal and special care and all hospital functions associated with the test and evaluation effort.

(5) Wilford Hall USAF Medical Center was to protect, idemnify, and save harmless Mt. Sinai, its employees, and medical staff from and against all liabilities, claims, and judgements of Wilford Hall USAF Medical Center patients, their families, or assigns arising out of the operation of the equipment, including, but not limited to, the operation of the computer in connection with the equipment.

3. Objectives.

a. System Objectives. The objectives of PPMS are to improve the delivery and outcome of patient care through the following:

(1) Improved awareness of the constantly changing physiologic state of the patient.

(2) Earlier recognition of unfavorable physiologic trends, and, therefore, earlier institution of therapy.

(3) Improved control of ventilatory therapy.

(4) Enhanced ability to recognize medical instrumentation malfunctions.

(5) Freeing physicians and nurses from clerical work.

b. Evaluation Objectives. Three prime evaluation objectives were derived from the system objectives. They are to determine the following:

(1) The degree to which the system fulfills its objective of improving the delivery and outcome of patient care.

(2) The acceptance of the system by operating personnel.

(3) The economic feasibility of the system in the military setting.

4. Hypotheses. One primary and 11 subsidiary hypotheses are associated with the first evaluation objective. They are listed below in the form of null hypotheses. No hypotheses were associated with the second and third objectives, but they were measured using techniques outlined in the next section.

a. Primary hypothesis. In the care of patients with critical problems of the heart and lungs, utilization of a PPMS will, when compared to present methods, have no effect on the delivery and outcome of patient care.

b. Subsidiary hypotheses.

(1) In the care of patients with critical problems of the heart and lungs, utilization of a PPMS will, when compared to present methods, have no effect on the rate and causes of mortality.

(2) In the care of patients with critical problems of the heart and lungs, utilization of a PPMS will, when compared to present methods have no effect on the length of patient stay in the ICU.

(3) In the care of patients with critical problems of the heart and lungs, utilization of a PPMS will, when compared to present methods, have no effect on the total time of ventilatory support.

(4) In the care of patients with critical problems of the heart and lungs, utilization of a PPMS will, when compared to present methods, have no effect on the time to vascular stability.

(5) In the care of patients with critical problems of the heart and lungs, utilization of a PPMS will, when compared to present methods, have no effect on cardiac crises.

(6) In the care of patients with critical problems of the heart and lungs, utilization of a PPMS will, when compared to present methods, have no effect on respiratory crises.

(7) In the care of patients with critical problems of the heart and lungs, utilization of a PPMS will, when compared to present methods, have no effect on vascular instability.

(8) In the care of patients with critical problems of the heart and lungs, utilization of a PPMS will, when compared to present methods, have no effect on the occurance of renal dysfunction, e.g., oliguria, anuria.

(9) In the care of patients with critical problems of the heart and lungs, utilization of a PPMS will, when compared to present methods, have no effect on the occurance of neurologic disasters, e.g., coma, stroke.

(10) In the care of patients with critical problems of the heart and lungs, utilization of a PPMS will, when compared to present methods, have no effect on the types, amounts, and duration of medication utilized.

(11) In the care of patients with critical problems of the heart and lungs, utilization of a PPMS will, when compared to present methods, have no effect on the type and number of laboratory tests ordered.

SECTION B - METHODOLOGY

5. Hypothesis Testing. Hypotheses were tested by comparing Test and Control Group patients. Test Group patients are ICU patients monitored during the test period using PPMS. Control Group patients are patients who were selected

from ICU patients prior to the installation of PPMS. Patient selection was based on diagnosis, age, sex, and medical condition at the time of admission. The selection process is illustrated in Appendix C.

a. Age Group Determination. For the purpose of evaluation, all Test and Control Group patients were divided into age groups using the Department of Health, Education and Welfare groupings for morbidity. They are as follows:

(1) Under 1 year

(2) 1 - 4 years

(3) 5 - 14 years

(4) 15 - 24 years

(5) 25 - 34 years

(6) 35 - 44 years

(7) 45 - 54 years

(8) 55 - 64 years

(9) 65 - 74 years

(10) 75 - 84 years

(11) 85 years and over

b. Medical Condition. The medical condition of patients at admission was given as an integer between zero and ten and is the sum of points awarded for each of the five following areas:

(1) Duration of cardiopulmonary pump run (heart-lung machine):

(a) 2 points 0 - 30 minutes

(b) 1 point 31 - 90 minutes

(c) 0 points 91 minutes or longer

(2) Renal/Cerebral function

(a)	2 points	Normal function
(b)	1 point	Minor dysfunction of either or both systems
(c)	0 points	Major dysfunction of either or both systems

(3) Myocardial performance

(a)	2 points	No support required
(b)	1 point	Responding to inotropic stimulation
(c)	0 points	Inotropic stimulation with poor response

(4) Respiratory status

(a)	2 points	Spontaneous ventilation
(b)	1 point	Assisted ventilation
(c)	0 points	Controlled ventilation

(5) Units of blood transfused

(a)	2 points	2 or fewer units
(b)	1 point	2 - 6 units
(c)	0 points	More than 6 units

c. Test and Control Group Comparability. In order to have meaningful results, it is important that the test and control groups be comparable. That is, they should be composed of patients having similar age, sex, diagnosis, and similar medical condition at the time of admission. Adherence to the previously outlined matching process should insure that the groups are comparable. Nevertheless, standard statistical methods were used to test comparability.

(1) A test for the difference between means was used to compare the sex composition of the group.

(2) Chi-Square analysis was used in comparing the diagnosis composition of the group.

(3) It was originally planned to use a one way analysis of variance to compare age and medical condition, but these variables were not normally distributed. Therefore a form of test for the difference between means using the t disbribution was used.

d. Data Collection. Data was collected by four nurses and one blood gas technician during the period of September 1976 through May 1977. They used a data collection form designed prior to the beginning of the data collection effort. The form required that following data concerning the patients be collected:

(1) Age

(2) Sex

(3) Diagnosis

(4) Medical Conditions.

(5) Mortality

(6) Total time in ICU

(7) Total time ventilatory support required

(8) Time to vascular stability

(9) Medication required for each quarter of admission

(10) Laboratory tests required for each quarter day of admission

(11) Cardiac crises, respiratory crises, vascular instability, renal dysfunction, and neurologic disasters will be quantified each quarter of admission using the following scale:

Table 1 - Quantification of Crises

Code	Definition
0	No problem
1	Problem exists, but no treatment is required
2	Problem exists, but patient is responding to treatment
3	Problem exists and patient is not responding to treatment

e. Hypothesis Testing. Hypotheses were tested using the data listed above.

(1) Hypothesis 4b(1) was tested using a test for the difference in proportions.

(2) Hypotheses 4b(2) through 4b(4), 4b(10) and 4b(11) were tested using a test for the difference between means.

(3) Hypotheses 4b(5) through 4b(9) were tested using an index based on the occurrence and severity of crises. Cardiac crises, respiratory crises, vascular instability, renal dysfunction and neurologic disaster were

quantified each quarter day of admission using the scale given in Table 1. An average, called the "crisis index", was calculated for each quarter day. Test and control groups were compared graphically and using a test for the difference between means.

6. Economic Feasibility of PPMS. The economic feasibility of PPMS was tested by converting change in length of stay, change in medication utilization, and change in numbers of laboratory tests into dollar figures. If the total monetary value of the changes represents a dollar savings when projected over the life expectancy of the system, then PPMS is considered economically feasible.

7. System Acceptance. System acceptance was measured through qualitative and quantitative methods.

a. Qualitative Methods. The qualitative measurement was accomplished by means of interview questionnaires administered after three months of PPMS use and again at the end of the test period. The questionnaire consisted of 27 statements. Users were asked to indicate the extent to which they agreed with the statement by circling the appropriate number from one to ten. Selection of the number "10" indicated strong agreement with the statement, while selection of the number "1" indicated strong disagreement. Some statements were concerned with user opinion of the system while other statements required the user to indicate how he felt members of his functional user category would feel about PPMS.

b. Quantitative Methods. Quantitative measurement of system acceptance was accomplished through the system's record of utilization by each user type. This measure was obtained by coded keyboard entry without the knowledge

of the user. Issues which were recorded include user type, length of interaction, type of interrogation and frequency of interaction. It was assumed that the patterns and frequency of use over the entire test period would reflect system utility and acceptance.

8. Limitations.

a. Sampled Population. The sampled population for this study was the patients, staff, and facilities of Wilford Hall USAF Medical Center during the period 1 July 1976 through 31 December 1976. No attempt should be made to generalize beyond this scope. Further restrictions on the sampled population follow:

(1) Facilities used were restricted to the Intensive Care Unit located within the surgical suite.

(2) Patients monitored were restricted to patients having severe problems of the heart or lungs located within this ICU.

(3) Staff members involved were restricted to thoracic surgeons, anesthesiologists, nurses and blood gas technicians who provided medical care to monitored patients.

b. Time Lag between Control Group and Test Group. The time lag between Test Group patients and Control Group patients was as much as a year. This introduced the possibility of new variables such as new innovations in medicine, turn over in personnel and increased competence of personnel. Some personnel associated with this evaluation felt that the effect of the time

lag was negligible, especially when compared to the effect of a learning curve factor which could result from selecting test and control group patients from the same period. By learning curve factor we mean that staff members may have learned the physical characteristics associated with certain medical conditions. The staff members would then be able to apply what they learned to control group patients and effect the outcome of their treatment.

c. Data were collected by a succession of four nurses and one blood gas technician. Although data collectors worked individually, each knew what data had been previously collected. Nevertheless, medical records are subject to interpretation. Since interpretation can vary from person to person, data may have not been collected consistently. However, we do not feel that reliability was seriously effected, because data collectors collected data for both test and control group patients. Assuming that each data collector was consistent in his interpretation, this helps to negate the difference in interpretation among data collectors.

d. No depreciation is normally used in determining costs in Air Force hospitals. Therefore, it was not considered in determining the cost effectiveness of PPMS.

e. Due to a malfunction within the system's record of utilization, the interaction of users with PPMS was not recorded for all days PPMS was in use.

SECTION C - FINDINGS

9. Background Data. Background data includes sex, age, primary diagnosis, and the condition of patients at the time of admission into the ICU. Background data is tested to determine the comparability of test and control group patients. Any significant differences must be considered in drawing conclusions relative to the hypotheses.

a. Sex. The sex of test and control group patients is given in Table 2. Test and control groups were compared using a test for the difference between proportions. The difference was found to be not significant at the .05 level of significance. This indicates that the two groups have similar structure according to sex.

Table 2 - Sex

Sex	Test Group Patients	Control Group Patients
Male	58	54
Female	24	27
	82	81
	70.7% Male	66.7% Male

b. Age. Table 3 provides an outline of the age of test and control group patients. A test for the difference between means indicates that the difference between age for the two groups is not significant at the .05 level of significance. This indicates that test and control group patients have comparable ages. Similar tests also indicate that the average age for male patients is about the same for test and control group patients, and the average age of test group female patients is about the same as control group female patients.

Table 3 - Age

Age Group	Number of Test Group Patients	Number of Control Group Patients
Under 1	2	0
1-4	2	3
5-14	5	9
15-24	3	5
25-34	5	2
35-44	14	14
45-54	22	18
55-64	26	22
65-74	2	8
75-84	1	0
85-up	0	0
Total	82	81
Average	43.817	44.037

c. Primary Diagnosis. The primary diagnoses of the test and control group patients are given in Appendix D. No statistical method was used to test the significance. Nevertheless, it does appear that the diagnoses are about the same for both groups.

d. Medical Condition. As previously indicated, medical condition was represented by a number from one to ten based on five categories: pump run, renal/cerebral function, myocardial function, respiratory status, and units of blood transfused. The average medical condition for test and control group patients is compared in Appendix E according to sex and age group. A test for the difference between means was used to compare differences between test and control group averages. It showed that difference was significant at the .05 level of significance. Differences were also significant for pump run, renal/cerebral function, and respiratory status. Slightly different results are obtained when the differences in medical condition are tested for male and female patients. The difference in total medical condition is significant at the .05 level of significance only for male patients. Similarly, the difference in pump run is significant only for male patients. In addition, the difference in Renal/Cerebral Function is not significant for male patients or female patients. All other results are the same as the results for all patients combined.

e. Comparability of Test and Control Group. Test and control group structures are roughly comparable. Despite fact that some differences are

significant, most lie within ranges which were considered acceptable prior to the test. These ranges are a difference of one point in total medical condition and 10 years in age. The difference in average age for female patients exceeded the 10 year range, but the difference was not significant. All significant differences will be considered when appropriate in the discussion of mortality and morbidity.

10. Mortality. Mortality rates for test and control group patients are outlined in Table 4. Tests for the differences between means indicate that no differences

TABLE 4 - MORTALITY

	Control Group Patients	Test Group Patients
Male		
Survived	51	53
Expired	3	5
Mortality Rate	5.6%	8.6%
Female		
Survived	23	22
Expired	4	2
Mortality Rate	14.8%	8.3%
Total		
Survived	74	75
Expired	7	7
Mortality Rate	8.6%	8.3%

When male and female patients were considered jointly, the level of significance was .0559, just missing the cut off point. The reduction in average length of stay would have been significant if it has been reduced an additional 41 minutes, without changing the standard error of the difference. It was established in paragraph 10 that the medical condition of test group patients at the time of admission was significantly worse than for control group patients. Considering these factors, one might conclude that the length of stay is reduced for patients having equal medical condition at the time of admission.

b. Time Ventilatory Support Required. The average time of ventilatory support required is summarized in Table 6. It was established in paragraph 10 that test group patients had a respiratory status that was significantly worse than control group patients. Nevertheless, test group patients required less time ventilatory support than control group patients. All reductions shown in Table 6 are significant at the .05 level of significance. In addition, all Type II errors are greater than .10.

Table 6 - Time Ventilatory Support Required

	Control Group Patients	Test Group Patients
Male	52.174 hours	29.020 hours
Female	62.877 hours	25.547 hours
Total	55.742 hours	28.297 hours

are significant at the .05 level of significance. Further, the Type II error for all patients combined is less than .10, and the Type II error for male patients is less than .10. Hence, it was concluded that the mortality for these two groups was the same. However, the Type II error for female patients is .1788. Hence, no conclusion can be reached concerning the difference in mortality rate for female patients.

11. Morbidity.

a. Time in ICU. Table 5 gives the average time in ICU for test group, control group, male, and female patients. None of the differences in average for test and control group are significant at the .05 level of significance. In addition, all Type II errors are greater than .10. When these two factors are considered jointly no conclusion can be reached. The level of significance indicates that one should not accept the alternate hypothesis that the length of stay was decreased for test group patients. The Type II errors indicate that one should not accept the null hypotheses that the lengths of stay are the same for both groups of patients.

Table 5 - Time in ICU

	Control Group Patients	Test Group Patients
Male	72.244 hours	59.555 hours
Female	99.756 hours	67.835 hours
Total	81.415 hours	61.978 hours

c. Time to Vascular Stability. Time to vascular stability is given in Table 7.

TABLE 7 - Time to Vascular Stability

	Control Group Patients	Test Group Patients
Male	41.141 hours	39.356 hours
Female	68.123 hours	30.710 hours
TOTAL	50.135 hours	36.826 hours

No conclusion can be reached when male and female patients are combined because the difference in means is not significant at the .05 level of significance and the Type II error is greater than .10. If male and female patients are considered separately, however, it is possible to determine conclusions. For male patients the Type II error was .0643, and for female patients, the difference was significant at the .05 level of significance. This implies that there was no difference in time to vascular stability for male patients, but there is evidence that the time to vascular stability was reduced for female patients. This might be partially explained by the fact that female test group patients had a better Myocardial Function and Renal/Cerabral Function than female control group patients at the time of admission, even though these differences were not significant.

12. The Occurence of Crises. Five types of clinical crises were considered in studying the delivery and outcome of patient care. The number of patients having each type of crisis is given in Table 8. Looking at test group patients, a test for the difference between proportions indicates that there was a significant reduction in the number of cases of hypotension and pneumonia, but an increase

in the number of cases of hypertension and atalectasis. Unfortunately, this tells nothing about the severity of the crisis, the duration of the crisis, or whether the crisis recurred. The method of comparison given in paragraph 5b was developed for this reason. Appendix F provides a graphic comparison of crisis index by quarter of the day for each crisis other than sinus arrhythmia and catatonia.

Table 8 - Numbers of Crises

Type of Crises	Control Group Patient	Test Group Patients
Cardiac Crises		
Severe Ventricular Arrhythmia	3	7
Ventricular Arrhythmia	24	15
Myocardial Failure	26	20
Respiratory Crises		
Atalectasis	17	45
Pneumonia	10	1
Vascular Instability		
Hypotension	24	10
Hypertension	21	46
Renal Dysfunction		
Oliguria	18	15
Anuria	9	6
Neurologic Disorder		
Coma	2	2
Other		
Sinus Arrhythmia	1	0
Catatonia	1	0

a. Cardiac Crises. Cardiac crises are compared in Appendix F.a. As indicated by the continuous lower graph, control group patients appeared to fare better for severe ventricular arrhythmia, and test group patients appeared to fare better for ventricular arrhythmia and myocardial failure. The differences between indices for severe ventricular arrhythmia only appeared to be real. A test for the difference between means revealed that differences were not significant despite the fact that the control group patients reach stability 12 quarters (three days) sooner. Some of the differences in index were real for ventricular arrhythmia and myocardial failure. For ventricular arrhythmias, test group patients had an index which was significantly better during quarters 6 through 9 and 12. It appears that the two groups of patients were about equal in cardiac crises with control group patients faring better for sever ventricular arrhythmia, and test group patients faring better for ventriuclar arrhythmia and myocardial failure.

b. Respiratory Crises. Respiratory crises are of primary interest because PPMS is a respiratory oriented system. Because of this factor, it was not expected that test group patients would have the relatively high index for atalectasis which is reflected in Appendix F.b. The difference in index was significant only for the first four quarters. This is consistant with the significant difference in respiratory status previously discussed. Control group patients had a better respiratory status when they entered the ICU and a better atalectasis index during the first day in the ICU.

c. Vascular Instability. Indices of vascular instability for test group patients and control group patients are compared in Appendix F.c. The two types of vascular instability considered were hypotension and hypertension. Test group patients had a significantly better hypotension index than control group patients during quarters 7 through 12 and 14 through 18. Further, test group patients reached stability 38 quarter days sooner. In contrast, control patients had a significantly better hypertension index than test group patients during the first four quarters and stabilized eight quarters earlier.

d. Renal Dysfunction. Appendix F.d. provides a comparison of indices for renal dysfunctions. Test group patients have indices for both anuria and oliguria which are apparently lower than the indices of control patients. For the most part, however, the differences in index are not significant. A test for the difference between means reveals that the differences are significant only for the anuria indices during quarter days 15 through 17. Control group patients having oliguria stabilized two quarters sooner than test group patients, but for patients having anuria, test group patients stabilized 34 quarter days sooner than control test group patients. Thus, there is little evidence that PPMS had any effect on the occurrence of renal dysfunction, although there is some evidence that patients having anuria stabilize sooner.

e. Neurologic Disasters. The only type of neurologic disaster which occurred was a coma. The coma indices for test and control group patients are graphed in Appendix F.e. There were two case of coma in each group.

The main difference between test and control groups is that for control group patients the comas occurred later and had a longer duration. This does not appear to be significant because all patients who had a coma expired. Thus there is little evidence that PPMS had an effect on the occurrence of coma.

f. Other Crises. There was one case each of sinus arrhythmia and catatonia among control group patients. Both lasted for only one quarter, and neither required treatment. Neither event was considered significant.

g. Discussion. Crisis indices seemed to follow a pattern which was apparent for most crises. The pattern is most visible for ventricular arrhythmia and myocardial failure, the differences were not significant during the first five quarters, and for hypotension the differences were not significant during the first six quarters. At this time, the indices for test group patients became significantly better than indices for control group. However, no differences were significantly different following quarter 21. Test group patients had an index which was significantly higher for atalectasis during the first four quarters and for hypertension during the first five quarters. This appears to be the result of the relative condition of patients groups at the conclusion of surgery rather than a difference which developed in the ICU room. During these early time periods, test group patients improved rapidly in relation to control group patients and differences were never again significant even though control group patients stabilized sooner. The trend seems to indicate that PPMS is most beneficial to the patient during at most the first five to six days in the ICU.

After this amount of time the patient has improved to the point that PPMS is no longer helpful. One might further infer that PPMS is most beneficial for patients who are seriously ill.

13. Medication. Medication given to all patients is listed in Appendix G. A"test for the difference between means"shows that the difference in the number of doses per patient is significant for only three drugs: nitropursside, digitalis, and manitol. For test group patients this indicated an increase in the use of nitropursside but a decrease in the use digitalis and manitol. These changes are consistent with the occurrence of crises just discussed in paragraph 12.

a. Nitropursside is used to treat patients having hypertension. Hence, the increased use nitropursside reflects the increased incidence rate of hypertension.

b. Digitalis is used to treat patients having myocradial failure. Test group patients had a significantly lower index than control group patients during quarters six through ten, and their index "zero" two quarters sooner. This accounts for the decrease in the amount of digitalis required.

c. The amount of manitol required by test group patients was reduced despite the fact that there was little difference between control group patients and test group patients for oliguria index and anuria index. The difference is probably best explained by the relatively rapid stabilization of test group patients. Their index reached "zero" 35 quarters days sooner than for control group patients. Thus, some control group patients still required manitol almost nine days after test group patients had stabilized.

14. Laboratory Tests. The number of laboratory tests required for test and control group patients are compared in Table 9. Test for the difference between mean indicate that differences were significant only for hematology, renal chemistry, and hepatic chemistry. There is no apparent reason for these differences.

Table 9 - Laboratory Tests

Type of Test	Tests Per Control Group Patient	Tests Per Test Group Patient
Blood Gas Analysis	41.605	46.146
Coagulation Analysis	2.358	2.537
Hematology	31.049	14.244
Renal Chemistry	1.494	0.463
Hepatic Chemistry	0.568	0.146
Enzyme Studies	1.123	0.610
General Chemistry	19.358	14.573
Blood Culture	0.012	0

The difference in the number blood gas analyses required for test and control group patients is not significant. Nevertheless, it is surprising that test group patients required more blood gas analyses considering their reduced stay in the ICU, and their reduced requirement for ventilatory support. Further, test group patients initially had a much higher index for atalectesis but improved more rapidly than control patients. Thus, the only possible reason for this increase is that blood gas analyses were often used as a cross check against the information from the computer. In many instances, treatment had already been instituted as a result of computer calculation. Blood gas analysis was used to verify the validity of this treatment.

15. Economic Feasibility. PPMS is considered to be economically feasible if the cost of operating PPMS represents a saving when compared to standard procedures. The change in cost derived in Table 10 includes all hospital costs. This table assumes that the change in length of stay developed in paragraph 11a is real and not merely due to chance. All "minus" signs indicate a decrease.

TABLE 10 - Cost Savings

Test Group Patients	61.978 hours/patient
Control Group Patients	81.415 hours/patient
Change/Patient	- 19.437 hours/patient
Patients/Year	188
Total Change/Year	- 3654.156 hours/year = - 152.2565 days/year
Cost/Day	$380.72 per day
Total Change per Year	-$57,967.09

The number of patients per year is an estimate based upon the number of patients (94) monitored using PPMS during the six month test. The cost per ICU bed day is an estimate derived by the Associate Administrator/Resource Management at Wilford Hall USAF Medical Center. The cost was developed using a ratio of average daily nursing (RN) hours per ICU patient to average nursing hours for all patients (for a one month period-Mar 77) times the average total cost per inpatien

day as calculated in the March 1977 Medical Expense Report (RCS: HAF-ACF (M&O)7148, Part 7). Special statistics were maintained by the Department of Nursing for the month of March 1977 which reflected on a daily basis the number of RN hours per 24 hours period for each nursing unit and the number of patients by nursing unit. A summary of that data for March 1977 is provided in Appendix H.

It is true that in this methodology the ratio of average nursing hours per ICU patient to the average nursing hours per non-ICU patient, i.e., 4.97 to 1, would have been the most accurate measure of the relative cost intensity of an ICU patient day versus a non-ICU patient. However, the ICU to non-ICU ratio was not used because the average cost per non-ICU patient day is not available within the existing Medical Expense Reporting system. The only available cost data are average cost per day for all patients. For this reason, the ratio of average nursing hours per ICU patient to average nursing hours for all patients was used as the relative measure of cost in this methodology. A mathematical proof of this methodology starting from total dollars per day cost is provided in Appendix I.

The cost of operating PPMS includes the purchase price maintenance, and requirements for supplies. The purchase cost is estimated to be $70,000 to $100,000 depending upon the number to be purchased and the company. Engineering specifications will be drafted by Air Force personnel, and the contract will be awarded based upon adherence to the contract. Cost effectiveness is dependent upon life expectancy and the number purchased.

Finally, it should be noted that this cost saving is not a factor which will appear in the annual budget, but rather will be realized in terms of available medical care and possible increased utilization of the ICU.

16. User Acceptance of PPMS.

a. Qualitative Analysis. User acceptance was measured by means of interview questionnaires which were administered during October 1976, just after the mid point of the test, and again during January 1977, following the end of the test. This paragraph summarizes the responses to all statements other than 13 through 17, and 19 through 24. These statements are considered in a later paragraph. Complete results of both surveys are outlined in Appendix K.

(1) Composite survey results. Survey results indicated some increase in user opinions from the time of the first survey to the time of the second survey. Nevertheless, users still did not indicate preference of PPMS to the manual system used before PPMS was installed. Further, they did not agree that PPMS should be retained in Wilford Hall or placed in other Air Force hospitals. The responses to statements applicable to these ideas were in the undecided range, and did not necessarily imply disagreement. This sometimes indicated a difference of opinion among user groups.

(2) Technicians were by far the most receptive user category. They prefered PPMS to the manual system of monitoring patients used before PPMS was installed (ref statements 5 and 6). Further, they feel PPMS should

be retained in Wilford Hall USAF Medical Center (statement 27) and that it should be used in Air Force hospitals in general (statements 25 and 26). The technicians felt that PPMS provided a better system of charting patient information, that PPMS provided more complete information, more accurate information, and that PPMS permitted better medical care. As one technician stated, technicians are sometimes alone in the ICU. PPMS is helpful in this situation because it provides them information which they could have otherwise obtained only from a physician or a nurse. They did agree with other users in feeling that PPMS would be better if it were interfaced with a typewriter which would provide a one page shift report, in contrast to bulky five page reports provided by a hardcopier which was in use during the test.

(3) Anesthesiologists showed the largest increase in opinion of all user groups. When the second interview questionnaire was administered, they indicated some tendency to prefer PPMS over the manual system used before PPMS was installed. They would like to see PPMS retained in Wilford Hall USAF Medical Center and, to a lesser extent, they feel that PPMS should be placed in Air Force hospitals in general. Like technicians, but to a lesser extent, they feel PPMS provides a better system of charting patient information, more complete information, and permits better medical care. Unlike technicians, they are not certain that PPMS provides more accurate information. Anesthesiologists also agreed that PPMS would be improved if it were interfaced with a typewriter that would provide one page shift reports.

(4) Surgeons were the least receptive of all user groups, and their opinion deminished between October 1976 and January 1977, the dates of the

two opinion surveys. Surgeons did not like PPMS, and they did not want PPMS retained at Wilford Hall or placed in Air Force hospitals in general. Surgeons did not feel that PPMS provided a better method of monitoring patients, nor did they feel PPMS permits better medical care. In addition, they did not feel that PPMS provided more complete information or more accurate information. This is somewhat of a reversal of opinion, because in October there was some tendency to agree that information provided was more complete. Most surgeons did not feel that interfacing a typewriter with PPMS would improve their opinions. Their main concern was that PPMS did not provide enough information concerning cardiac parameters, and does not have a good visual display. One surgeon added that there is a tendency to pay more attention to the machine than the patient. As a case in point, he cited an incident when one of his patients almost died while people were standing around watching the machine.

(5) Nurses indicated the largest decrease in opinion between the two surveys. This was surprising considering the effort placed on training (see statement 4). One of the most common comments that was provided by nurses during the October survey was concerned with inadequate training. Just before the first opinion survey, a nurse went to Pacific Medical Center for training in the use of PPMS. After returning to Wilford Hall USAF Medical Center, this nurse held seminars on the use of PPMS. This effort is reflected by the response to the second opinion survey (see statement 4). Despite training efforts, nurses do not like PPMS, but rather their responses place them in the undecided range. Nurses would not retain PPMS in Wilford Hall USAF Medical Center if they were responsible for making the decision

(see statement 27) and they would not place it in other hospitals (see statements 25 and 26). They do not feel that it provides a better method of charting patient information and is a duplication of efforts. Nurses are undecided concerning the accuracy of data and whether PPMS permits better medical care.

Following resolution of the problem of inadequate training, one of the major concerns among nurses appeared to be shift reports. Although PPMS provided hard copy capability, a shift report required five pages and was not of good quality. Nurses were not allowed to put these copies in the patient's medical records, so they were forced to prepare a separate shift report, thus causing some duplication of effort. Surprisingly, only three of eight nurses felt that interfacing a typewriter to produce one page shift reports would effect their opinions. Of the five who felt a typewriter would have no effect, one had a positive opinion which she felt could not be improved. Only three of the four not having favorable opinions gave a reason. One said that she does not use the system while another said that it is just another thing to fool around with. The third nurse said that her main concern is that people pay more attention to the machine than to the patient and there is a danger of machine dependency.

b. Quantitative Analysis. Table 11 provides a summary of system use by month for all users combined. Figures in the table indicate the average number of interactions with PPMS per day. Although the average number of interactions per day was cyclic, there does appear to be an upward trend. This is supported by statistical analysis. The average number of interactions

per day for the second three month period (342) is about 51 percent higher than the number of interactions per day for the first three month period. A test for the difference between means indicates that this difference is significant at the .05 level of significance. However, no attempt should be made to generalize beyond this six month period, becuase there is no evidence that the trend will continue. Appendix L provides a breakdown of interactions per day for each user category. It should be noted that this reflects only the users who interacted with the system. It does not necessarily indicate who used the information.

TABLE 11
COMBINED USE OF PPMS

Month	Total Interaction	Results	Analyses	Entries	Calibrations	Calculating Routines	Debugging Routines	Index	Other	Invalid
July	321.5	70.2	50.0	107.4	23.2	6.3	3.8	39.1	17.8	3.7
August	201.1	42.9	33.2	79.0	18.1	4.1	0.8	14.3	6.6	2.1
September	94.6	21.8	11.9	38.8	7.2	2.6	1.3	4.2	5.8	1.0
October	461.7	150.0	35.0	193.5	4.8	38.5	2.5	13.3	22.3	1.8
November	393.8	106.1	36.5	186.2	22.6	21.9	1.1	4.1	13.1	2.2
December	190.5	29.9	8.1	114.7	15.5	10.9	0.6	3.0	7.2	0.6
TOTAL	274.2	65.2	32.7	117.1	18.4	11.1	1.6	14.6	11.3	2.2

(1) Technicians were by far the most prolific system users. They were responsible for about 72 percent of all interactions with PPMS. This was expected because technicians made most (91 percent) data entries. Data entries made up 54 percent of their interactions. However, it was not expected that they would request results and analyses more than other users, though this is consistent with results of the opinion questionnaires.

(2) Nurses were the second most prolific users. Their total number of interactions per day for the second half of the test period increased by a factor of 2.3 over the first half. This implies increased acceptance of PPMS but is not consistent with the opinion survey results.

Nurses had 2.2 times as many interactions as anesthesiologists and 3.2 times as many interactions as surgeons. The majority (59.6 percent) of their interactions were requests for results or analyses. Surprisingly, they requested key board entry "R6"(listed as "calculating routines") more than surgeons or

anesthesiologists. This key board entry provided data concerning drug infusions.

(3) The majority (64 percent) of interactions made by anesthesiologists were requests for results and analyses. The number of interactions per day for the second half of the test increased only about 13 percent.

(4) Surgeons had fewer interactions with PPMS than any other functional users. The number of interactions per day during the second half decreased by 27 percent. Thus, the surgeons use of PPMS was consistent with their responses to the opinion survey.

c. Summary. Technicians and anesthesiologists demonstrated acceptance of PPMS. Technicians demonstrated the highest degree of acceptance on the opinion survey and the highest rate of use for PPMS. Both increased throughout the test. Anesthesiologists demonstrated a favorable opinion of PPMS on the second opinion survey, and they had the largest increase in opinion. Although their number of interactions with PPMS was low, it did increase during the second half of the survey.

The nurses' acceptance of PPMS was uncertain. Their opinion of PPMS, as demonstrated by the second opinion survey, was in the undecided range. In addition, they demonstrated the largest decrease in opinion despite a large increase in the number of interactions with the system.

Surgeons did not accept PPMS. Their opinion, as reflected in both surveys, was low, and their number of interactions was small. Both decreased during the second half of the test.

17. Reliability of PPMS. In evaluating the reliability of PPMS, we considered both the downtime of the system and the number of calibrations required. During the evaluation, we found that these two criteria are not independent.

Downtime was included in statements 13-16 of the interview questionnaire (see Appendix II). Only the technicians agreed that the downtime was acceptable. All other user groups were in the undecided range, but surgeons showed some tendency to disagree. Fortunately, most user groups agreed that the downtime did not seriously effect patient care. Only the surgeons did not agree, and their responses fell in the undecided range. Thus, the survey results indicate some concern over downtime.

A log of problems with PPMS was maintained in the blood gas laboratory. According to this log, there were a variety of problems with PPMS. The log indicated that there were problems with the monitoring screen, the arterial and EKG displays, a faulty 0_2 analyzer, calibrations for cardiac monitoring, and problem with the computer in New York. The only two continuing problems concerned with gas calibrations and end expired CO_2. They presented a problem throughout the entire six month test period. Table 12 shows that an average of 18 calibrations were required per day, though these were obviously not all gas calibrations. The number of calibrations per day did not decrease, but rather increased as the test progressed. The average number of calibrations per day for the second half of the test was 19.1 as compared with 18.0 for the first half.

According to one of the blood gas technicians who maintained the maintenance log, most of the problems resulted from telephone interference. He felt that if PPMS were linked with a computer locally, the amount of interference would have been reduced substantially, and the downtime would have been reduced by more than 50 percent. If the present linking of PPMS to the computer in New York continues, it appears that these same problems will continue to occur.

18. Other Issues. Two system objectives were not addressed in the hypotheses. According to paragraphs 3a(1) and 3a(5), PPMS should improve the delivery and outcome of patient care through improved awareness of the constantly changing physiologic states of patients, and through freeing physicians and nurses from clerical work. Although these issues were not measured objectively, they were addressed in the interview questionnaire.

a. Awareness of Constantly Changing Physiologic States of Patients (statements 23 and 24). Again, as with many other issues addressed by the interviews questionnaires, there is disagreement among functional user groups. Technicians and anesthesiologists agree that, through using PPMS, they have increased their awareness of the physiologic states of patients. They also feel that other technicians and anesthesiologists would have the same opinion. Nurses and surgeons were uncertain with surgeons tending to disagree.

b. Freedom from Administrative Detail (statements 19-22). No functional user group agreed that PPMS provides more freedom than administrative details, because of the newness of the system and the necessity of having complete patient records. Both the manual and automated methods were employed. In reality, this was an increase in clerical exercises which was reflected in the survey. Near the end of the survey, permission to replace manual flow sheets with hard copies was requested of the hospital records committee. This permission was not secured before the end of the test period. In addition, only technicians felt that PPMS allows them to devote more time to patients' care. This is because technicians used the computer to calculate parameters they previously calculated manually. Surgeons and nurses disagreed with both

issues, while anesthesiologists were undecided. The nurses opinions appear to be related to shift reports. As previously stated, nurses were not allowed to use PPMS hard copies for shift reports and were forced to maintain separate records. Interfacing a typewriter with PPMS should resolve this problem, and this computer produced shift report should be considered an approved hospital document.

SECTION D

CONCLUSIONS

19. Conclusions:

a. PPMS had no effect on reducing patient mortality.

b. PPMS reduced total time in the ICU by 25%.

c. The most impressive effect of PPMS was the reduction in ventilatory support by 50%.

d. Time to vascular stability was shorter for PPMS patients, but not to a significant degree.

e. The various crises recorded showed that PPMS patients had a higher incidence of atelectasis and hypertension; however, these were rapidly corrected during the first six quarters.

f. Control patients had more problems with pneumonia, hypotension, arrhythmias, myocardial failure, oliguria, and anuria.

g. Drug requirements were different between the two groups; however, they reflected appropriate treatment of the existing medical problems.

h. PPMS had demonstrated a potential for cost effectiveness.

g. PPMS is most effective when used to monitor seriously ill patients.

i. PPMS was accepted by anesthesiologists and technicians but not by surgeons. Nurses were undecided.

j. The primary maintenance problems were associated with the telephone link of the system and computer.

k. Awareness of the constantly changing physiological states of patients was improved for anesthesiologists and technicians, but not surgeons. Nurses were undecided.

l. PPMS did not permit freedom from administrative detail.

SECTION E

RECOMMENDATIONS

20. Recommendations: Recommend that:

a. PPMS not be proliferated as it now exists.

b. Automated patient physiological monitoring efforts be continued.

c. A prototype system be procured competitively if an off the shelf system is available which has capabilities to include the following:

(1) Provide information concerning cardiac parameters needed by surgeons.

(2) Provide information concerning respiratory parameters needed by anesthesiologists.

(3) A visual display capability acceptable to both surgeons and anesthesiologists.

(4) A keyboard system which provides one page shift reports which can be placed in the patient's records.

d. The system should be a complete package rather than a system put together piece by piece.

e. PPMS should be used for patients having severe respiratory failure. Use should be restricted to Wilford Hall USAF Medical Center, and possible Malcolm Grow USAF Medical Center, Andrews AFB, Wash DC, and David Grant USAF Medical Center, Travis AFB, CA. These are the only medical centers which may have sufficient patients for the system to be cost justifiable.

APPENDIX A

PHYSIOLOGICAL PARAMETERS MONITORED

PRIMARY MEASUREMENTS	CALCULATED PARAMETERS
Arterial Pressure	Cardiac Output, Cardiac Index
Venous Pressure	Systolic, Diastolic, Mean Arterial Pressure
Pulmonary Artery Pressure	dP/dt of Arterial Pressure
Heart Rate	Systolic, Diastolic, or Mean Pulmonary Artery Pressure
Airway or Esophageal Pressure	Mean Central Venous Pressure
Respiratory Flow	Heart Rate
Respiratory Gas pO_2 and pCO_2	Pulse Rate
Body Temperature	Central or Skin Temperature
	Respiratory or Minute Volume
	Tidal Volume
	Peak Airway Pressure
	Static Airway Pressure
	Lung Compliance
	Lung Non-Elastic Resistance
	Expiratory Flow-Volume Curves
	End-Expiratory (alveolar) pCO_2
	End-inspiratory, End-expiratory pO_2
	Oxygen Uptake, CO_2 Output, Respiratory Quotient

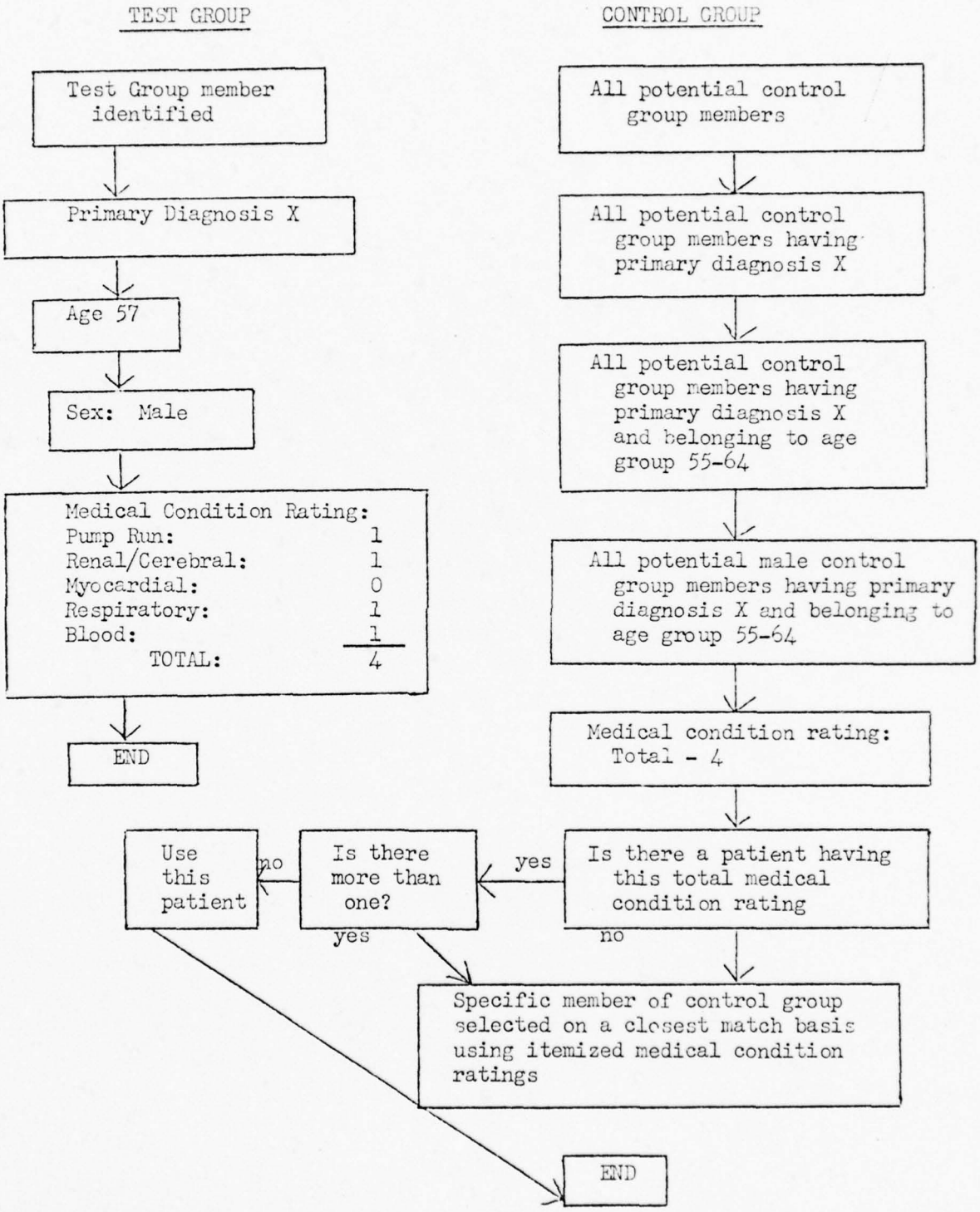
APPENDIX B

INSTRUMENTS USED TO OBTAIN MEASUREMENTS

MEASUREMENT	INSTRUMENT
Arterial Pressure Venus Pressure Pulmonary Artery Pressure	Catheters in appropriate positions
Heart Rate	ECG using standard electrodes
Body Temperature	Thermistor probe
Respiratory Flow Respiratory Gas pO_2 and pCO_2 Airway or Esophageal Pressure	Modified Fleisch Pneumotachograph

APPENDIX C

CONTROL GROUP SELECTION PROCESS EXAMPLE



APPENDIX D

PRIMARY DIAGNOSIS

TEST GROUP

1.	Closure ventricular septal defect	5
2.	Closure patent ductus	3
3.	Tetrology of Fallot	3
4.	Closure of artrial septal defect	3
5.	Correction tricuspid atresia	2
6.	Resection thoracic aneurysm	2
7.	Mitral valve replacement	11
8.	Pericardiectomy	2
9.	Saphenous vein graft	36
10.	Aortic valve replacement	5
11.	Right colectomy	1
12.	Jejunostomy	3
13.	Aorto-iliac endarterectomy	1
14.	Portal-caval shunt	1
15.	Aortobifemoral graft	4
16.	Lobectomy	1

CONTROL GROUP

1.	Transposition of great vessels	1
2.	Coronary Artery Vein Graft	17
3.	Atrial septal defect	12
4.	Ventricular septal defect	1
5.	Subaortic stenosis	2
6.	Coarctation of aorta	1
7.	Pulmonary volve stenosis	1
8.	Aortic valve replacement	2
9.	Resection aortic aneurysm	16
10.	Left ventricular aneurysm	1
11.	Mitral valve replacement	5
12.	Portal caval shunt	2
13.	Exploratory lap lysis adhesions	2
14.	Carotid artery stenosis	1
15.	Gastro-jejunostomy	1
16.	Axillary bifemoral bypass	1
17.	Aortic valve replacement	3

CONTROL GROUP

Aortic Aneurysm	16
Saphenous Vein Graft	22
Aortic Valve Replacement	11
Mitral Valve Replacement	9
Repair Ventricular Septal Defect	3
Transposition of the Great Vessels	1
Atrial Septal Defect	11
Carotid Endarterectomy	1
Coarctation of the Aorta	1
Pulmonary Valve Replacement	1
Axilobiteuroral Bypass Shunt	1
Portocaval Shunt	1
Ventricular Aneurysmectomy	1
Idiopathic Hypertrohpic Subaortic Stenosis	1
Esophagogastrectomy	1
	81

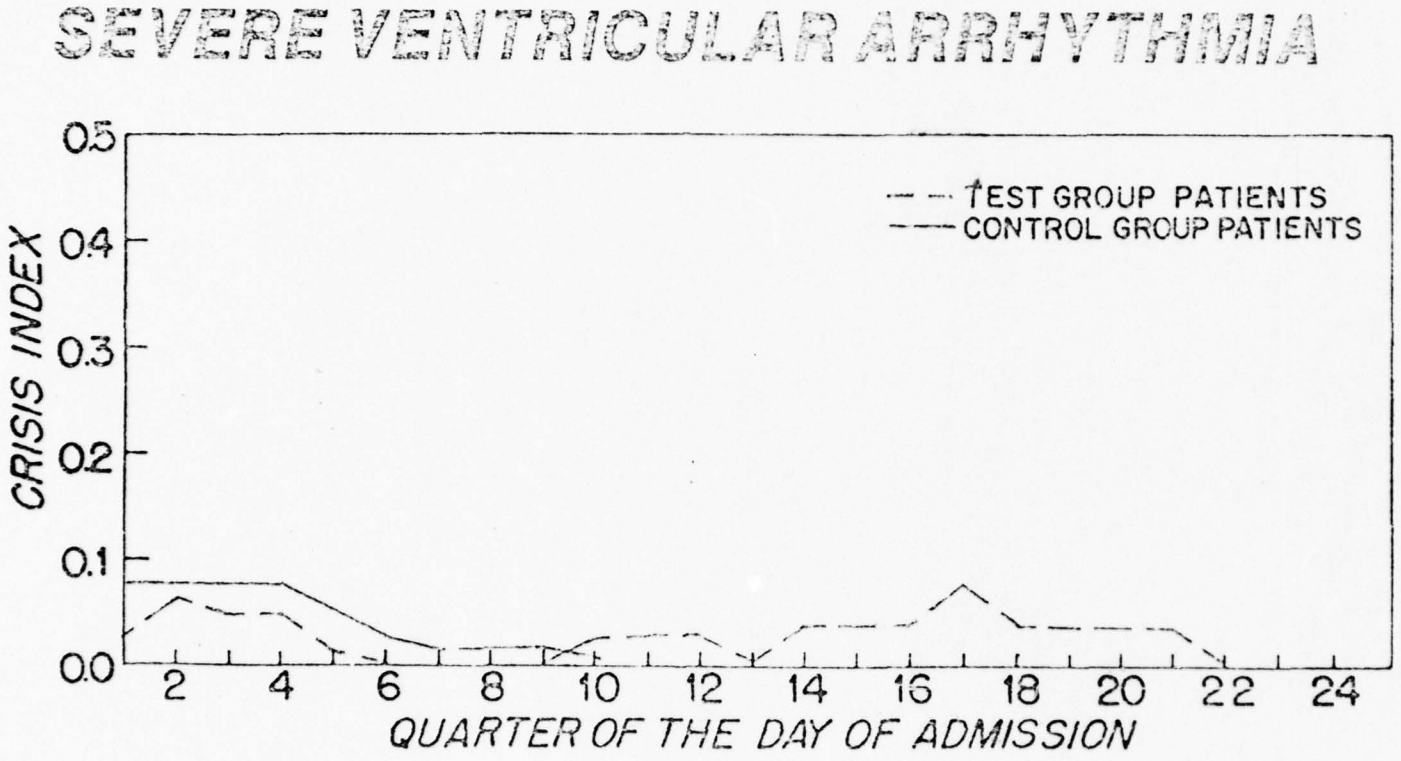
APPENDIX E

MEDICAL CONDITION

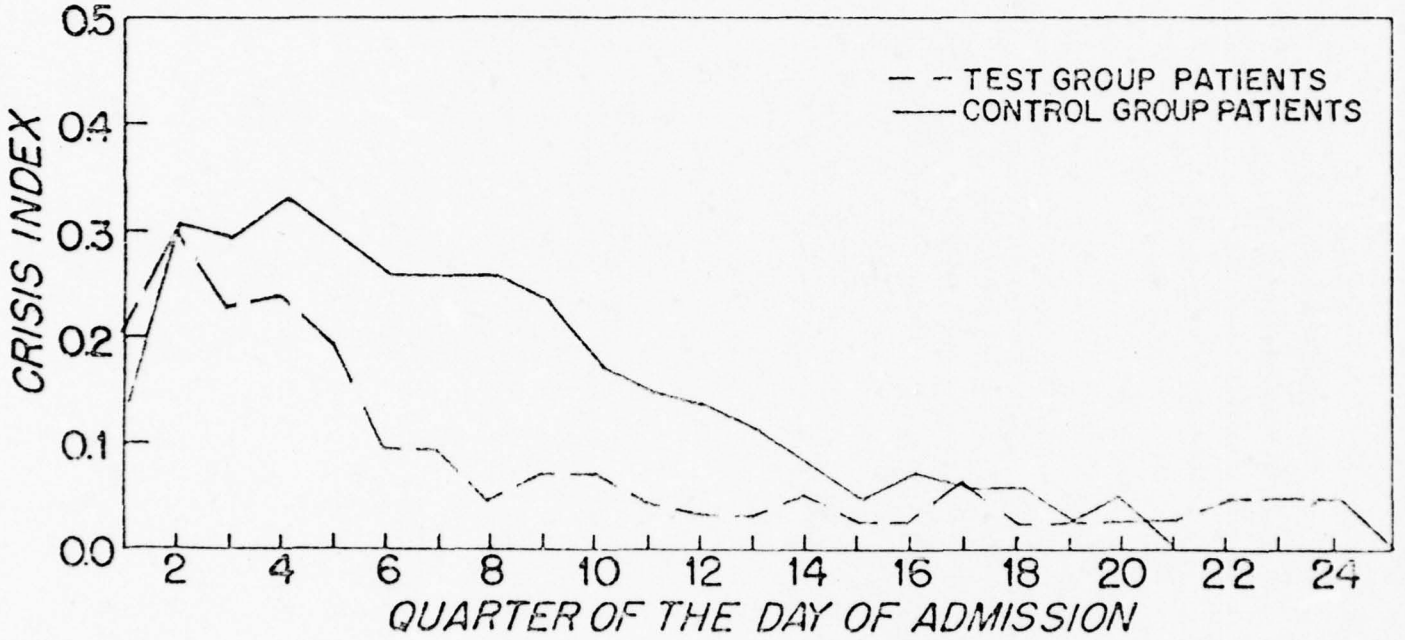
	PUMP RUN		RENAL/CEREBRAL FUNCTION		MYOCARDIAL FUNCTION		RESPIRATORY STATUS		UNITS OF BLOOD TRANSFUSED		TOTAL	
	Control Group	Test Group	Control Group	Test Group	Control Group	Test Group	Control Group	Test Group	Control Group	Test Group	Control Group	Test Group
Age Group												
Under 1	-	1.500	-	0.500	-	0.500	-	0.500	-	1.000	-	4.000
1-4	1.333	0.500	1.167	1.500	1.333	2.000	1.333	1.000	1.333	1.500	7.000	2.500
5-14	1.333	1.400	2.000	1.600	1.556	1.600	1.556	1.000	1.444	1.600	2.889	7.400
15-24	1.000	0.667	2.000	2.000	1.600	1.000	1.800	1.000	1.600	2.000	8.000	6.667
25-34	1.000	1.200	2.000	2.000	1.500	1.600	1.500	0.800	1.000	1.200	7.000	6.800
35-44	0.500	0.643	1.500	1.857	1.071	1.286	1.357	7.000	0.714	0.648	5.143	5.429
45-54	1.111	0.727	1.389	1.545	1.000	1.182	1.167	0.909	0.889	0.818	5.556	5.182
55-64	1.318	0.615	1.227	1.692	1.091	1.115	1.136	0.962	0.545	0.577	5.318	4.962
65-74	1.375	0.000	1.000	0.500	1.250	0.500	1.000	1.000	0.750	0.500	5.375	2.500
75-84	-	2.000	-	1.000	-	1.000	-	1.000	-	0.000	-	5.000
85-Up	-	-	-	-	-	-	-	-	-	-	-	0.000
TOTAL	1.111	0.767	1.457	1.634	1.185	1.207	1.272	0.939	0.877	0.829	5.901	5.280
SEX												
MALE	1.093	0.655	1.574	1.690	1.259	1.224	1.278	0.931	0.833	0.810	6.037	5.190
FEMALE	1.148	1.000	1.222	1.500	1.037	1.167	1.259	0.958	0.963	0.875	5.629	5.500

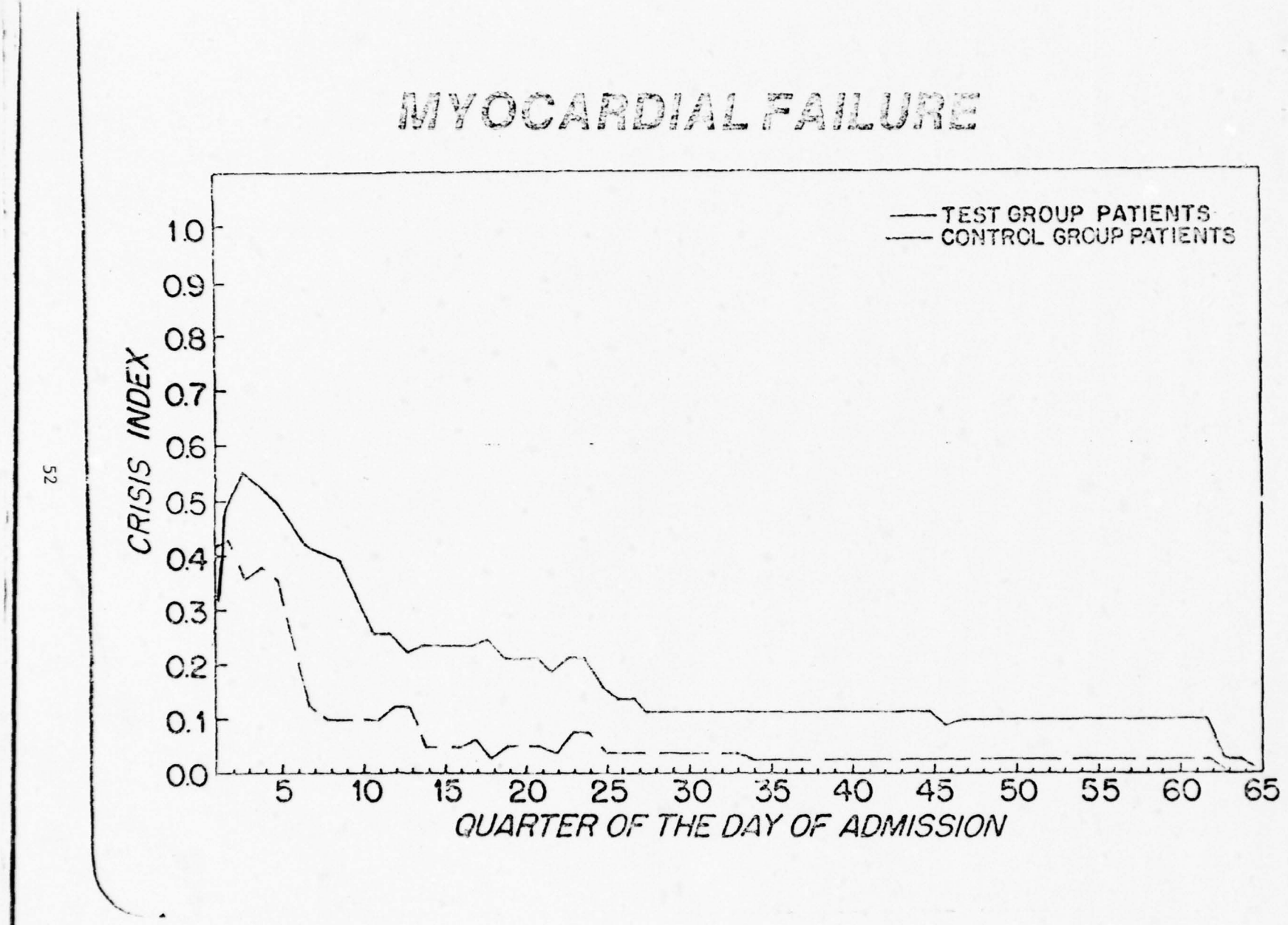
APPENDIX F

a. Cardiac Crises

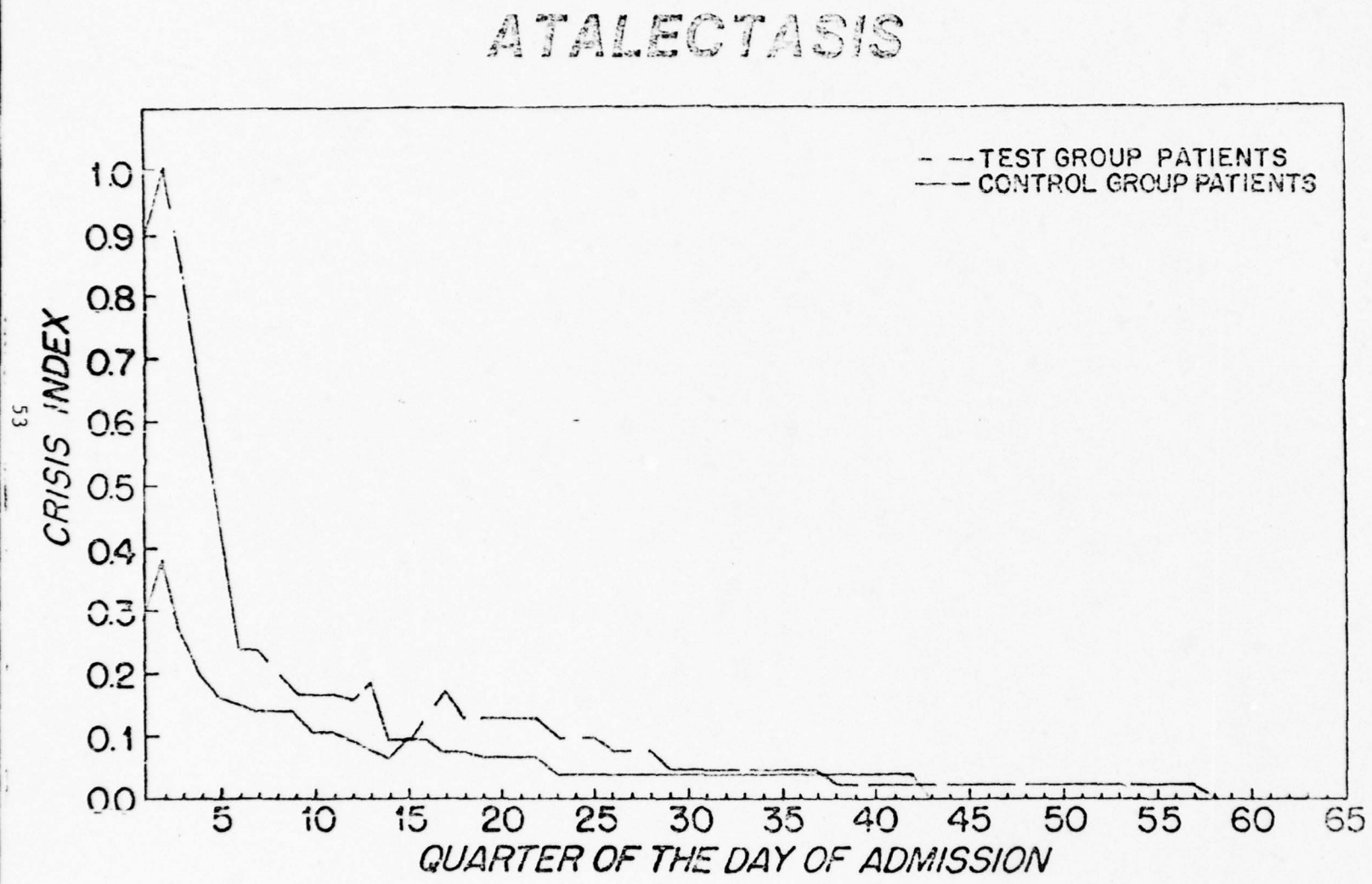


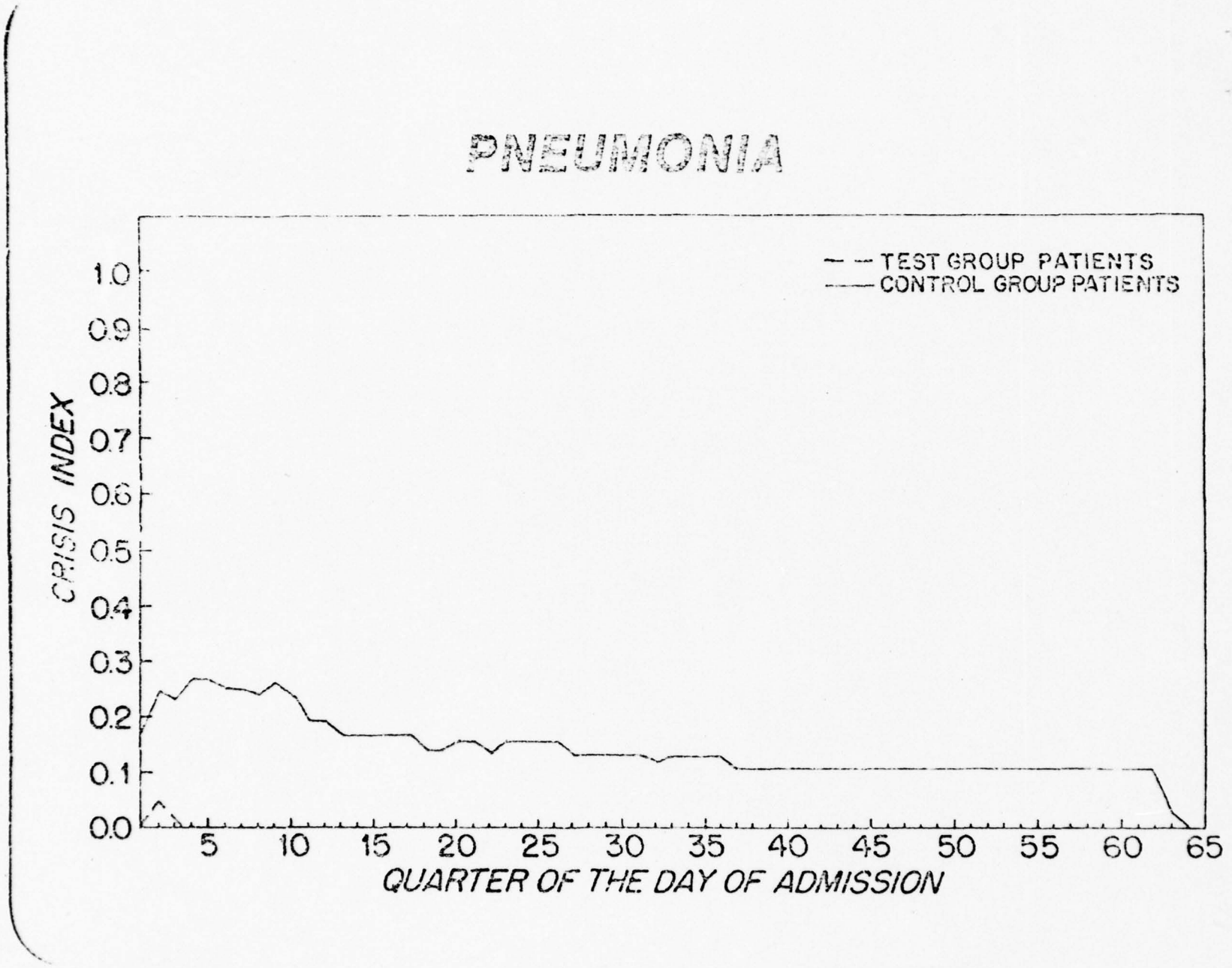
VENTRICULAR ARRHYTHMIA



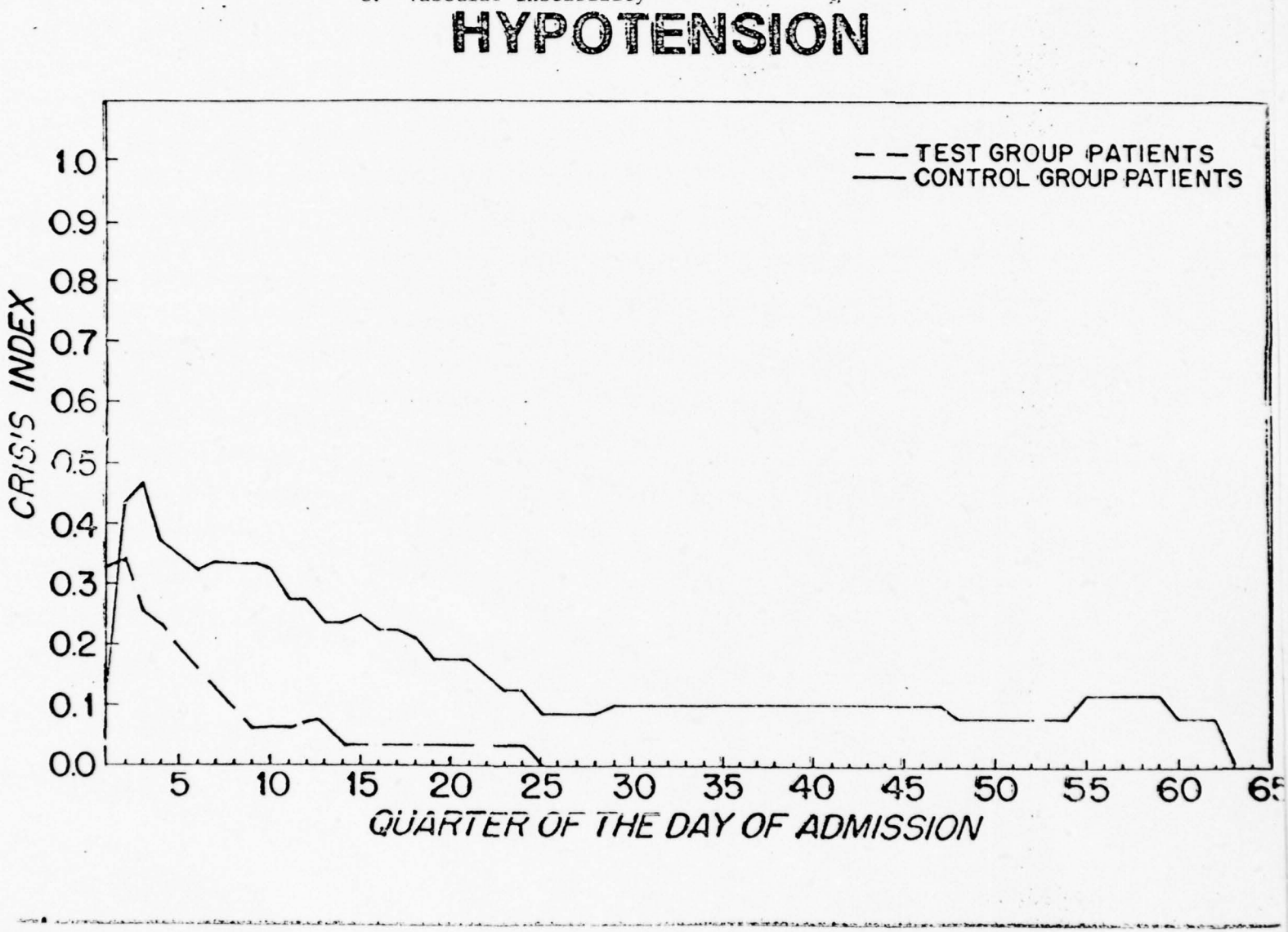

MYOCARDIAL FAILURE
TEST GROUP PATIENTS
CONTROL GROUP PATIENTS
CRISIS INDEX
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
5
10
15
20
25
30
35
40
45
50
55
60
65
QUARTER OF THE DAY OF ADMISSION

b. Respiratory Crises

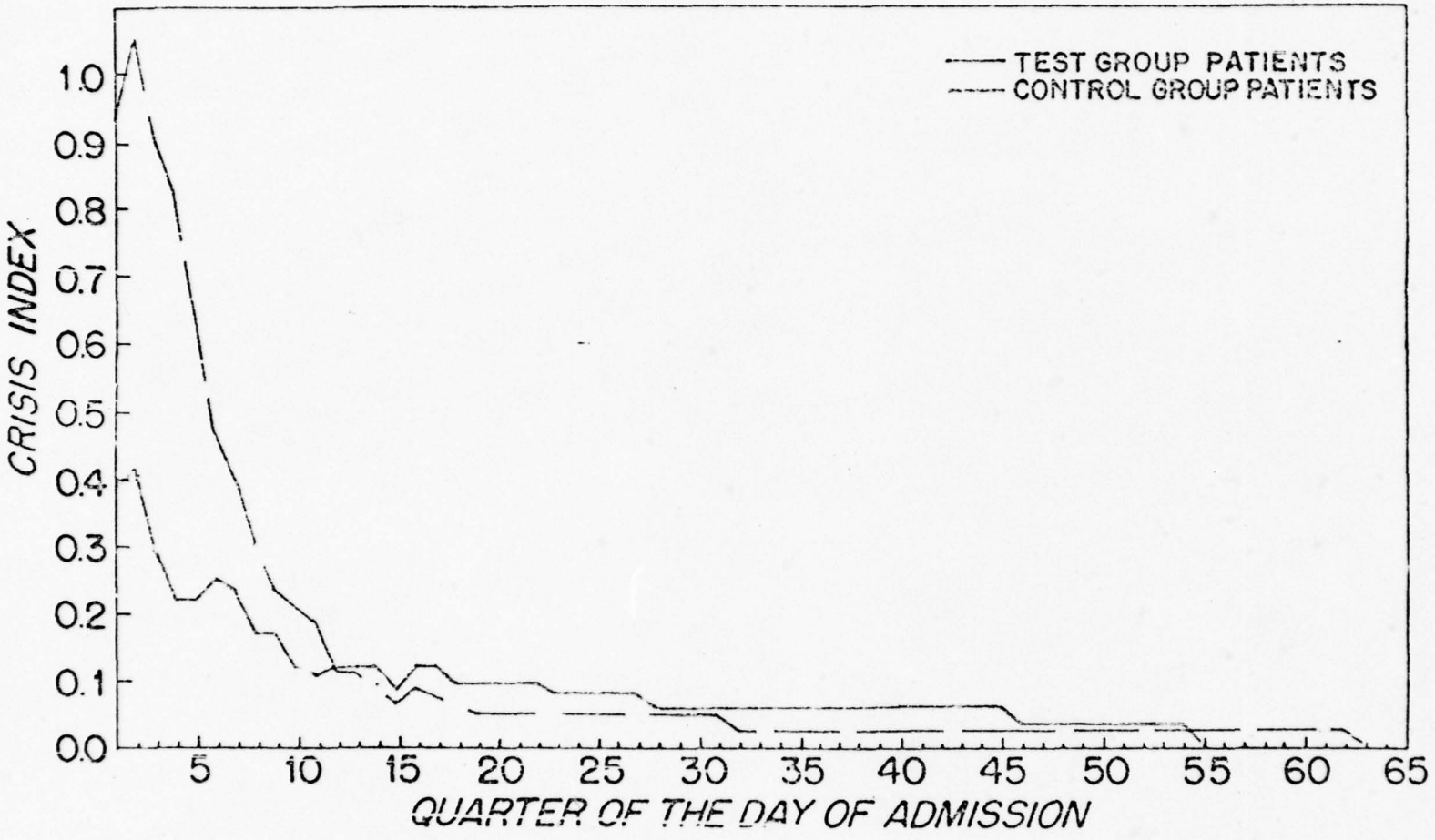



PNEUMONIA
TEST GROUP PATIENTS
CONTROL GROUP PATIENTS
CRISIS INDEX
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
5
10
15
20
25
30
35
40
45
50
55
60
65
QUARTER OF THE DAY OF ADMISSION

c. Vascular Instability

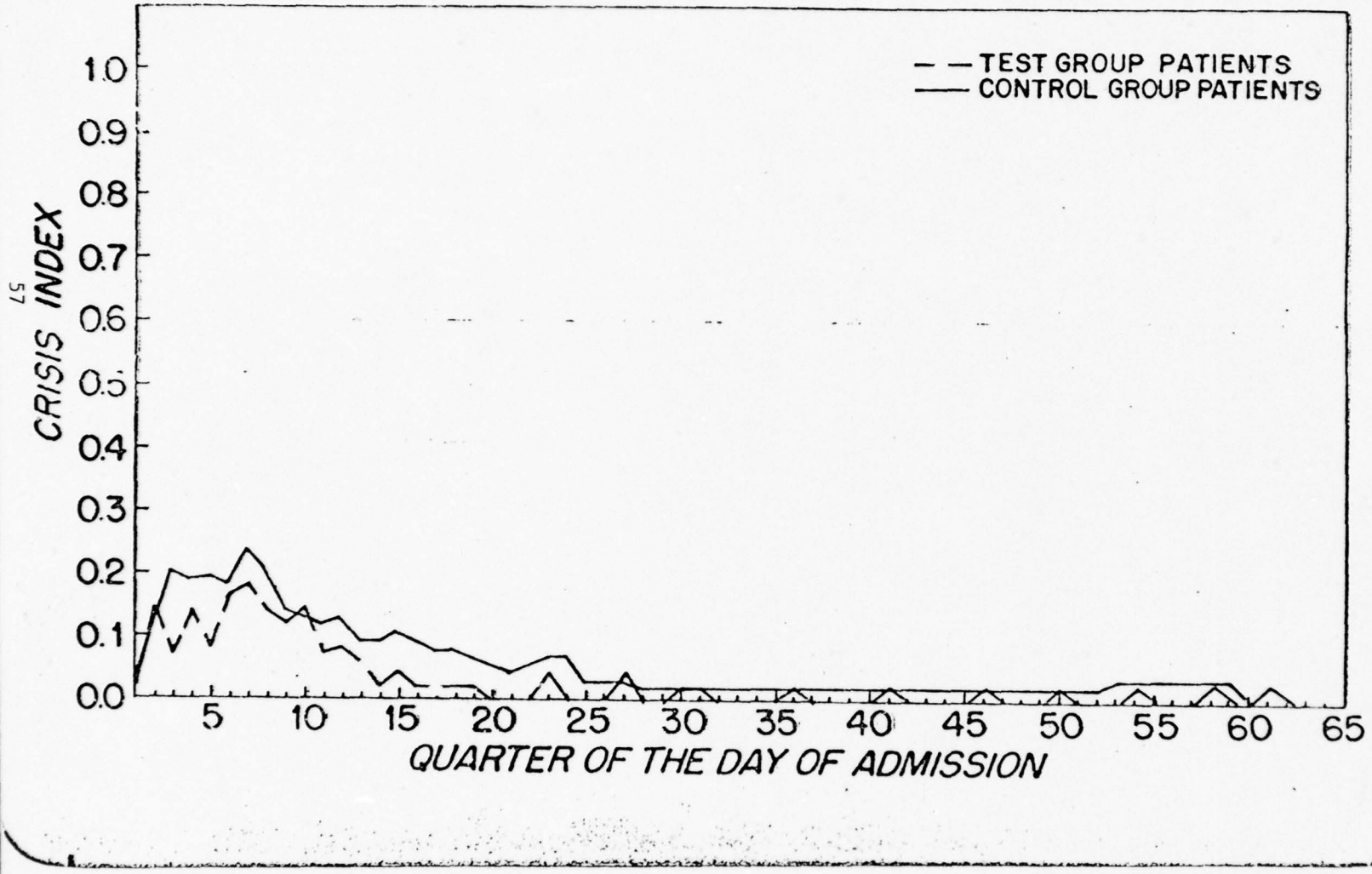


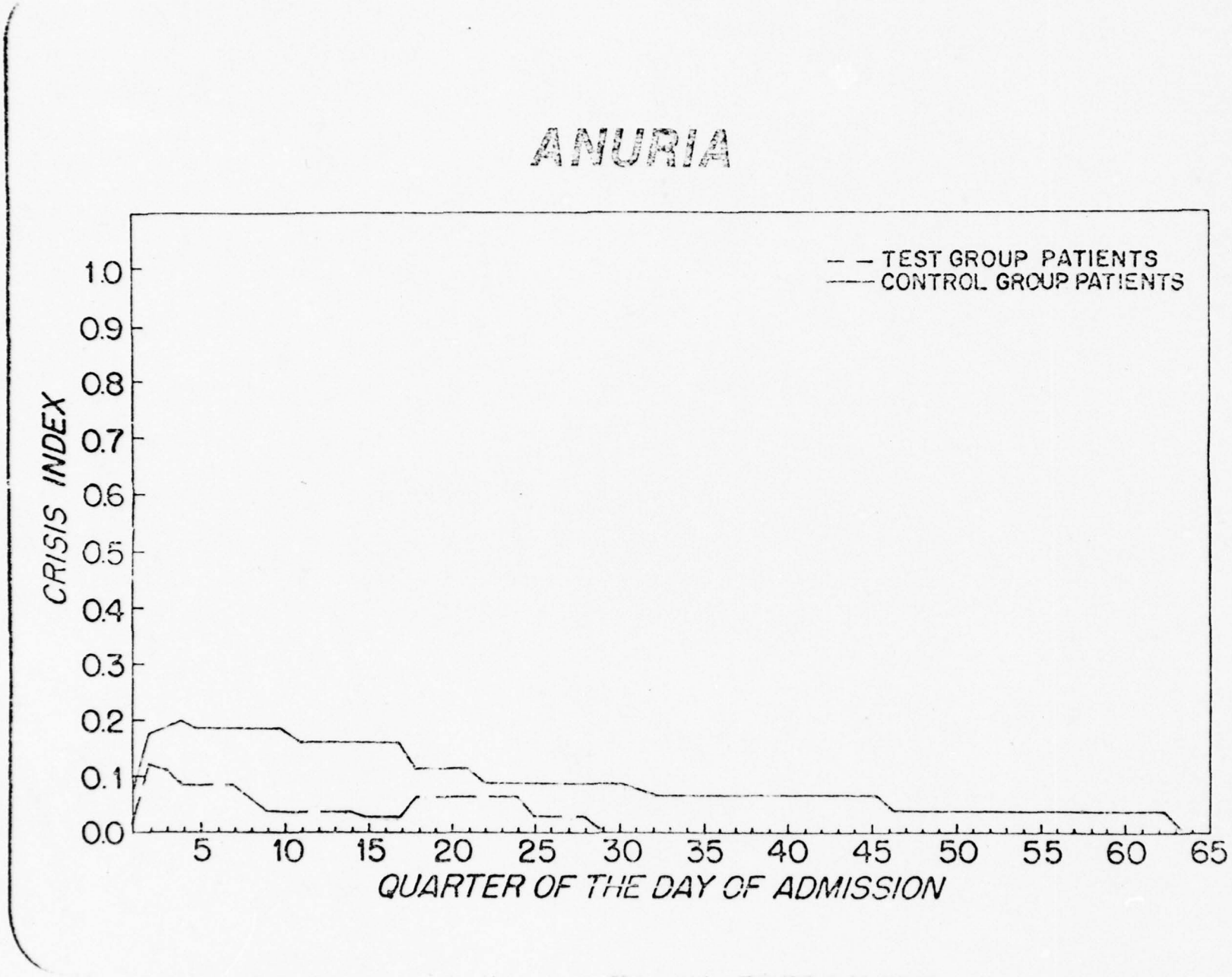
HYPERTENSION



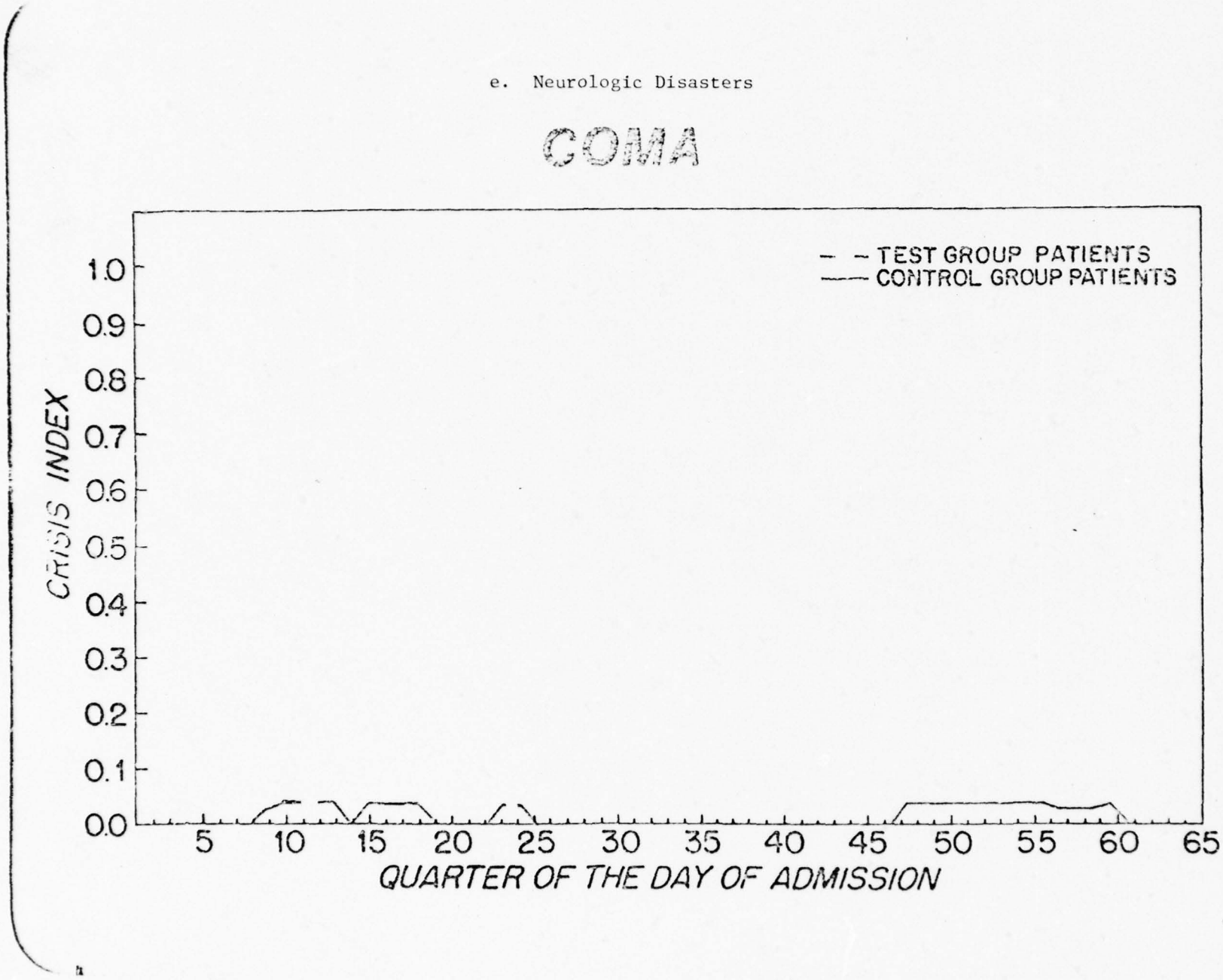
d. Renal Dysfunction

OLIGURIA




ANURIA
TEST GROUP PATIENTS
CONTROL GROUP PATIENTS
CRISIS INDEX
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
5
10
15
20
25
30
35
40
45
50
55
60
65
QUARTER OF THE DAY OF ADMISSION

e. Neurologic Disasters



APPENDIX G

MEDICATION

Type of Medication	Doses Per Control Group Patient	Doses Per Test Group Patient
Infusions		
Dopamine	1.617	1.756
Epinephrine	0.012	0.159
Lidocaine	1.111	1.841
Norepinepharine	0.000	0.000
Nitropursside	2.321	4.317
Isuprel	0.235	0.793
IM & IV		
Cardiac		
Xylocaine	0.210	0.427
Calcium	0.123	0.293
Digitalis	1.907	0.488
Vascular		
Steroid	0.679	0.085
Vasopressor	0.049	0.061
Ganglionic Block	0.000	0.12
Renal		
Lasiz	3.160	1.366
Edicrin	0.086	0.024
Manitd	0.160	0.012
Dilantin	0.012	0
Protamine Sulphate	0.012	0
Haldol	0.049	0
Aquamephyten	0.160	0
Thorazine	0.025	0
Antibiotics	0.062	0
Quinidine	0.630	0
Arfonad	0.198	0
Inderal	0.062	0

	Doses Per Control Group Patients	Doses Per Test Group Patients
Lerophad	0.025	0
Intropin	0.025	0
Isodril	0.111	0
Pronestyl	0	0.640
Atropine	0	0.155
Kefzol	0	1.656
Decadron	0	0.171
Peritoneal Dialysis	0	0.110
Neosynephrine	0	0.012
Leuophed	0	0.049
Sodium Bicarbonate	0.123	0.037
Valium	0.012	0.024
Solu Cortef	0.037	0.024
Aldomet	0.049	0.310
Apresoline	0.099	0.037

APPENDIX H

COST PER ICU BED DAY

	ICU UNITS	NON ICU UNITS	TOTAL
Average number of RNs assigned per 24 hour period	45.13	131.32	176.45
Average work day in hours	8.0	8.0	8.0
Average nursing (RN) hours available per 24 hour period	361.04	1050.56	1411.60
Average number of patients per day	5355	774.23	827.78
Average nursing (RN) hours per patient per day	6.74	1.36	1.71
Ratio of average nursing (RN) hours per ICU patient to non-ICU patient		4.96	
Ratio of average nursing (RN) hours per ICU patient to average nursing hours for all patients			3.94
Average total cost per patient day per March 1977 Medical Expense Report			$96.63
Estimated Average cost per ICU patient day			$380.72

APPENDIX I

COST PER ICU BED DAY - ALTERNATIVE METHOD

Average Nursing (RN) hours available per 24 hour period for March 1977	
For all patients	1411.60
For ICU patients	361.04
Percent of nursing hours attributable to ICU patients	25.58%
Total costs of inpatient care for period 1 October 76 - 31 March 77	$14,452,825
Portion of inpatient costs attributable to ICU patients	$ 3,697,033
Number of days (1 Oct 76 - 31 Mar 77)	182
Daily inpatient costs attributable to all ICU patients	$20,313
Average daily number of ICU patients for March 1977	53.55
Average cost per day	$379.33
Rounding Differences	1.39
Estimated Average Cost per ICU patient day	$380.72

APPENDIX J
SURVEY RESULTS

INSTRUCTIONS: Users were asked to indicate the extent to which they agreed with teach statement by circling the appropriate number. Selection of the number "10" indicated strong agreement with the statement, while selection of the number "1" indicated strong disagreement.

1. I like the Patient Physiological Monitoring System (PPMS)

User Category	First	Second	Difference
Anesthesiologists	4.80	6.13	+1.33
Surgeons	4.67	2.60	-2.07
Nurses	6.20	5.33	-0.87
Technicians	9.00	8.50	-0.50
Composite	5.61	5.29	-0.32

2. I like the manual system of monitoring patients used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	5.75	6.13	+0.38
Surgeons	6.67	6.20	-0.47
Nurses	6.40	7.89	+1.49
Technicians	4.00	4.50	+0.50
Composite	6.06	6.67	+0.61

3. I have heard few complaints concerning PPMS.

User Category	First	Second	Difference
Anesthesiologists	2.60	3.88	+1.28
Surgeons	3.67	2.60	-1.07
Nurses	4.40	4.78	+0.38
Technicians	6.00	8.00	+2.00
Composite	3.83	4.29	+0.46

4. I have received adequate training concerning PPMS.

User Category	First	Second	Difference
Anesthesiologists	3.40	4.75	1.35
Surgeons	7.17	6.60	-0.57
Nurses	2.80	6.56	+3.76
Technicians	9.00	10.00	+1.00
Composite	5.11	6.25	+1.24

5. Most _____ that I know would prefer PPMS to the manual system of monitoring patients used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	3.40	5.00	+1.60
Surgeons	2.83	3.00	+0.17
Nurses	3.80	2.89	-0.91
Technicians	7.00	8.00	+1.00
Composite	3.72	4.04	+0.32

6. I prefer PPMS to the manual system of monitoring patients used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	4.00	6.13	+2.13
Surgeons	3.00	2.00	-1.00
Nurses	5.40	5.44	+0.04
Technicians	6.50	8.50	+2.00
Composite	4.33	5.21	+0.88

7. Most _____ that I know would feel that PPMS provides a better system of charting patients than the manual system used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	4.40	6.50	+2.10
Surgeons	3.33	2.60	-0.73
Nurses	3.60	2.89	-0.71
Technicians	5.50	8.50	+3.00
Composite	3.94	4.50	+0.56

8. I feel that PPMS provides a better system of charting patients than the manual system used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	5.00	6.50	+1.50
Surgeons	3.33	2.00	-1.33
Nurses	6.20	3.67	+2.53
Technicians	5.50	9.00	+3.50
Composite	4.83	4.79	-0.04

9. Most _____ that I know would feel that PPMS provides more complete information than the manual system used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	5.00	8.13	+3.13
Surgeons	6.17	4.40	-1.77
Nurses	6.40	4.67	-1.73
Technicians	9.50	9.50	0.00
Composite	6.28	6.17	-0.11

10. I feel that PPMS provides more complete information than the manual system used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	6.40	7.88	+1.48
Surgeons	6.17	4.20	-1.97
Nurses	5.80	6.78	+0.98
Technicians	10.00	9.50	-0.50
Composite	6.56	6.83	+0.27

11. Most _____ that I know would feel that PPMS provides more accurate information than the manual system used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	3.80	5.88	+2.08
Surgeons	5.83	4.00	-1.83
Nurses	5.60	5.44	-0.16
Technicians	8.50	7.50	-1.00
Composite	5.50	5.46	-0.04

12. I feel that PPMS provides more accurate information than current manual methods.

User Category	First	Second	Difference
Anesthesiologists	3.80	5.50	1.70
Surgeons	3.17	3.80	0.63
Nurses	6.20	5.44	-0.76
Technicians	6.00	8.50	+2.50
Composite	4.50	5.38	+0.88

13. Most _____ that I know would feel that the downtime for PPMS has been acceptable.

User Category	First	Second	Difference
Anesthesiologists	2.40	5.13	+2.73
Surgeons	7.17	4.40	-2.77
Nurses	5.60	5.22	-0.38
Technicians	7.50	8.50	+1.00
Composite	5.44	5.29	-0.15

14. I feel that the downtime for PPMS has been acceptable.

User Category	First	Second	Difference
Anesthesiologists	2.40	5.13	+2.73
Surgeons	7.17	4.40	-2.77
Nurses	6.20	5.56	-0.64
Technicians	6.50	8.50	+2.00
Composite	5.50	5.42	-0.08

15. Most _____ that I know would feel that the downtime for PPMS has not seriously affected patient care.

User Category	First	Second	Difference
Anesthesiologists	8.00	7.38	-0.62
Surgeons	7.00	5.60	-1.40
Nurses	7.20	6.67	-0.53
Technicians	8.50	9.00	+0.50
Composite	7.50	6.88	-0.62

16. I feel that the downtime for PPMS did not seriously effect patient care.

User Category	First	Second	Difference
Anesthesiologists	8.60	7.38	-1.22
Surgeons	7.00	5.40	-1.60
Nurses	8.00	8.20	+0.22
Technicians	7.00	8.50	+1.50
Composite	7.72	7.33	-0.39

17. Most _____ that I know would feel that PPMS permits better medical care than the manual system used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	4.00	6.50	+2.50
Surgeons	2.83	4.60	+1.77
Nurses	4.80	5.44	+0.64
Technicians	8.50	9.00	+0.50
Composite	4.33	5.92	+1.59

18. I feel that PPMS permits better medical care than the manual system used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	4.20	6.00	+1.80
Surgeons	2.83	4.00	+1.17
Nurses	6.40	5.33	-1.07
Technicians	9.00	9.00	0.00
Composite	4.89	5.58	+0.69

19. Most _____ that I know feel that PPMS provides more freedom from administrative details than the manual system used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	4.40	5.00	+0.60
Surgeons	3.00	3.40	+0.40
Nurses	4.20	3.44	-0.76
Technicians	5.50	6.50	+1.00
Composite	4.00	4.20	+0.21

20. I feel that PPMS provides more freedom from administrative details than the manual system used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	4.40	5.00	+0.60
Surgeons	3.00	3.40	+0.40
Nurses	5.00	3.78	-1.22
Technicians	4.00	4.00	0.00
Composite	4.06	4.13	+0.07

21. Most _____ that I know would feel that PPMS saves them more time to devote to patient care than the manual system used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	4.60	5.00	+0.40
Surgeons	2.67	2.60	-0.07
Nurses	5.80	3.33	-2.47
Technicians	5.50	8.00	+2.50
Composite	4.39	3.96	-0.43

22. I feel that PPMS saves me more time to devote to patient care than the manual system used before PPMS was installed.

User Category	First	Second	Difference
Anesthesiologists	4.00	4.75	+0.75
Surgeons	2.67	2.40	-0.27
Nurses	5.40	3.33	-2.07
Technicians	5.00	8.00	+3.00
Composite	4.06	4.00	-0.06

23. Through using PPMS, most _____ that I know would increase their awareness of the constantly changing physiologic states of patients.

User Category	First	Second	Difference
Anesthesiologists	6.80	8.25	+1.45
Surgeons	4.50	5.20	+0.70
Nurses	7.20	5.89	-1.31
Technicians	9.50	10.00	+0.50
Composite	6.44	6.88	+0.44

24. Through using PPMS, I have increased my awareness of the constantly changing physiologic states of patients.

User Category	First	Second	Difference
Anesthesiologists	4.40	7.63	+2/93
Surgeons	2.67	4.20	+1.53
Nurses	6.80	5.33	-1.47
Technicians	9.00	10.00	+1.00
Composite	5.00	6.25	+1.25

25. Most _____ that I know would feel that PPMS should be placed in Air Force hospitals.

User Category	First	Second	Difference
Anesthesiologists	4.40	4.88	+0.48
Surgeons	2.50	3.00	+0.50
Nurses	4.60	4.22	-0.38
Technicians	5.50	9.00	+3.50
Composite	3.94	4.58	+0.64

26. I feel that PPMS should be placed in Air Force hospitals.

User Category	First	Second	Difference
Anesthesiologists	2.60	6.13	+3.53
Surgeons	2.67	3.80	+1.13
Nurses	6.80	4.78	-2.02
Technicians	9.00	9.00	0.00
Composite	4.50	5.38	+0.88

27. If I had the responsibility for deciding, I would retain PPMS in Wilford Hall.

User Category	First	Second	Difference
Anesthesiologists	3.20	7.13	+3.93
Surgeons	2.17	2.00	-0.17
Nurses	7.60	4.22	-3.38
Technicians	9.00	10.00	+1.00
Composite	4.72	5.21	+0.49

APPENDIX K

USER INTERACTIONS WITH PPMS

a. Nurses

MONTH	Total Interactions	Results	Analyses	Entries	Calibrations	Calculating Routines	Debugging Routines	Index	Other	Invalid
July	26.1	11.5	5.4	1.9	0.4	0.6	0.3	4.2	1.3	0.5
August	22.3	7.6	3.1	3.5	0.6	1.8	0.3	3.3	1.5	0.6
September	12.4	3.0	2.1	0.3	0.8	2.4	0.2	1.3	2.1	0.2
October	73.2	57.5	4.5	0.5	0.8	0.3	0.3	4.3	4.0	1.0
November	96.6	45.8	13.7	18.5	0.5	13.1	0.3	1.7	2.3	0.7
December	19.5	6.3	1.2	7.2	0.0	3.2	0.0	0.4	0.8	0.4
TOTAL	43.6	19.5	6.5	7.1	0.5	4.7	0.3	2.6	1.8	0.6

b. Technicians

MONTH	Total Interactions	Results	Analyses	Entries	Calibrations	Calculating Routines	Debugging Routines	Index	Other	Invalid
July	243.9	40.0	32.8	95.9	22.1	5.4	2.9	28.5	13.9	2.4
August	151.0	20.8	22.6	75.0	16.9	1.3	0.4	8.3	4.5	1.2
September	69.9	12.6	2.4	38.2	5.5	0.2	0.5	2.1	2.9	0.5
October	299.7	68.8	12.5	185.3	4.0	3.0	2.3	6.8	16.5	0.5
November	263.3	43.8	17.7	164.4	21.9	2.5	0.7	2.0	9.3	1.0
December	157.3	20.0	7.9	105.9	15.5	0.1	0.6	1.4	5.6	0.3
TOTAL	13.5	5.7	2.3	1.1	0.4	1.6	0.2	1.2	0.8	0.2

c. Surgeons

MONTH	Total Interactions	Results	Analyses	Entries	Calibrations	Calculating Routines	Debugging Routines	Index	Other	Invalid
July	21.5	6.4	5.3	3.5	0.5	0.3	0.5	2.9	1.7	0.4
August	12.4	6.4	2.2	0.4	0.5	0.9	0.0	1.3	0.5	0.2
September	9.0	4.3	0.9	0.3	0.8	0.1	0.7	0.8	0.8	0.3
October	29.5	10.3	6.3	0.3	0.0	10.3	0.0	1.5	0.5	0.3
November	11.5	6.7	1.2	0.4	0.2	2.4	0.0	0.2	0.4	0.1
December	4.8	0.7	0.0	0.6	0.0	2.2	0.0	0.7	0.6	0.0
TOTAL	13.5	5.7	2.3	1.1	0.4	1.6	0.2	1.2	0.8	0.2

d. Anesthesioloigsts

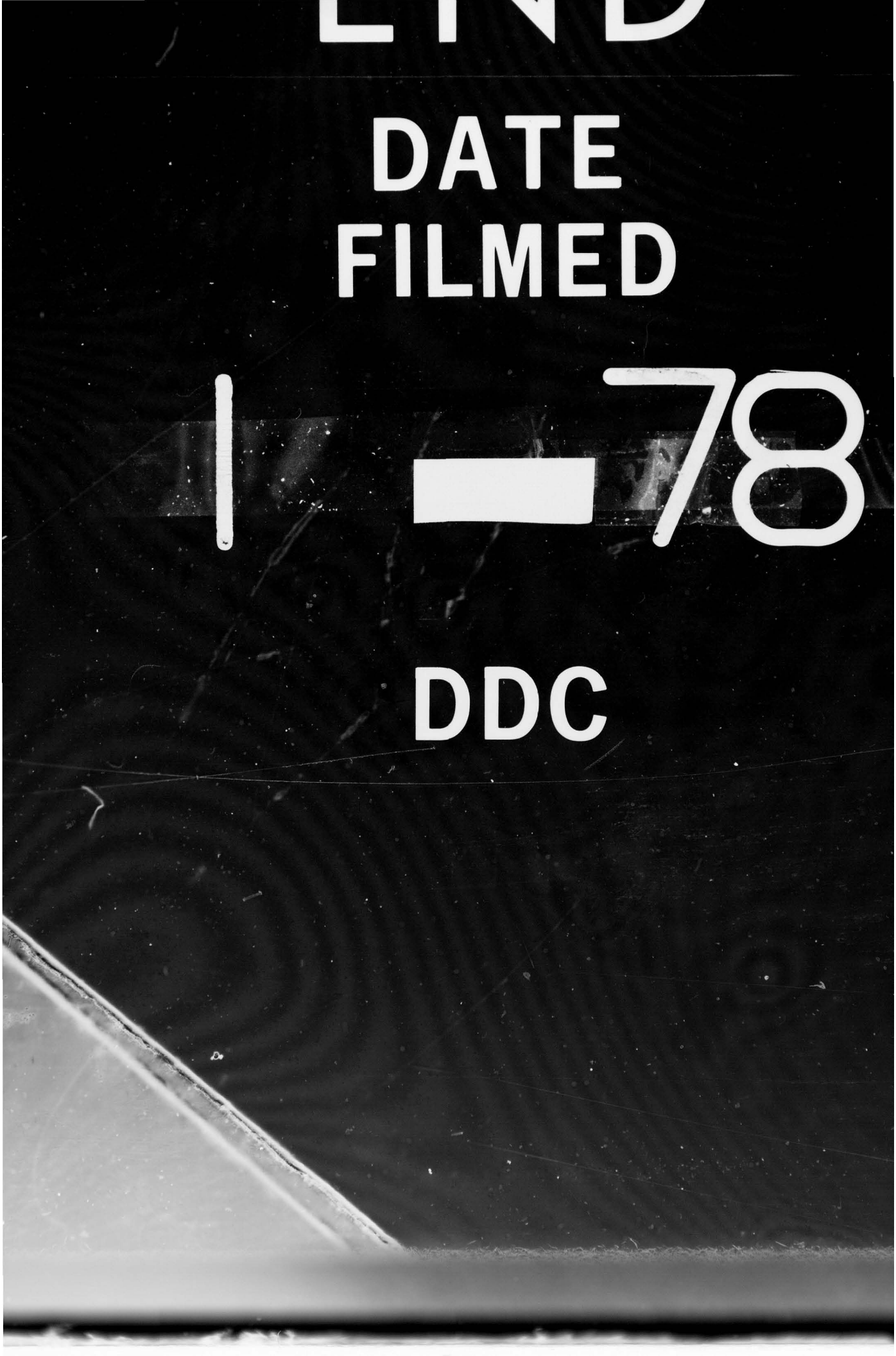
MONTH	Total Interactions	Results	Analyses	Entries	Calibrations	Calculating Routines	Debugging Routines	Index	Other	Invalid
July	29.8	12.3	6.5	6.1	0.3	0.0	0.0	3.5	0.7	0.4
August	15.4	8.1	5.3	0.2	0.1	0.0*	0.1	1.4	0.1	0.1
September	3.5	1.9	1.5	0.0	0.0	0.0	0.0	0.1	0.0	0.0
October	49.9	13.5	1.8	7.5	0.0	25.0	0.0	0.8	1.3	0.0
November	22.3	9.8	3.9	2.9	0.1	3.9	0.0*	0.2	1.1	0.4
December	10.3	2.9	0.4	0.9	0.0	5.4	0.0	0.5	0.2	0.0
TOTAL	19.6	8.4	4.1	2.5	0.1	2.5	0.0*	1.3	0.5	0.2

*Average per day is greater than 0 but less than 0.05

APPENDIX L

GLOSSARY

Test for the Difference Between Means	A statistical test used to determine if two averages are significantly different
Test for the Difference Between Proportion	A statistical test used to determine if two averages are significantly different
Level of Significance	The probability of incorrectly accepting an alternate hypothesis. Also called a Type I error
Type II Error	The probability of incorrectly accepting a null hypothesis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